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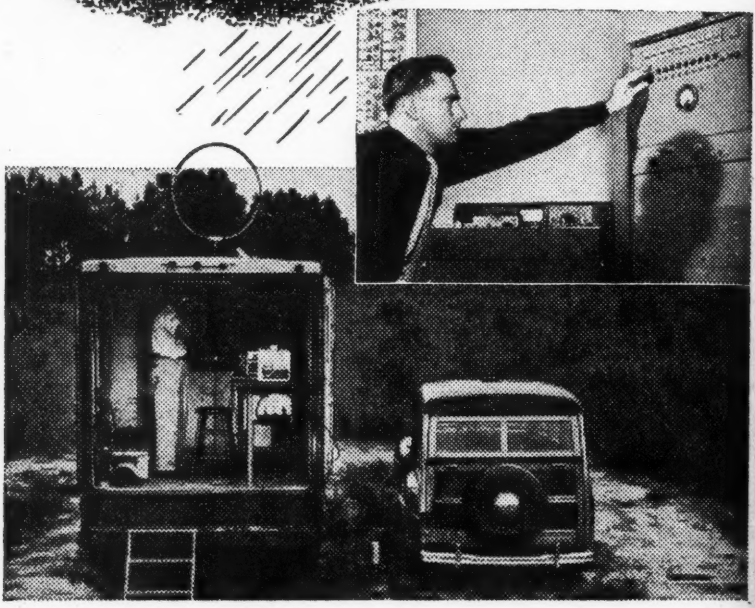
The American Society for Engineering Education

Thunder Hunters



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*Henry E. KILEY, engaged in Development Work, the Standard Machinery Company, Providence, Rhode Island; formerly Instructor in Mechanical Engineering, Massachusetts Institute of Technology; John PAUSTIAN, Assistant Professor, Department of Mechanical Engineering, University of Nebraska.

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Social and Political Forces Affecting Civil Engineering Education*

By N. A. CHRISTENSEN

Professor and Director, School of Civil Engineering, Cornell University

The American desire to preserve our way of life in a world which is becoming overpopulated and stimultaneously compressed by more rapid means of communication is the basic cause of social and political stress in the United States. The United States is strong but the opponent which threatens her is the most powerful enemy our country has ever faced. In a larger sense the conflict is between democratic and communistic ideas. The United States and Russia are simply the leaders of the opposing groups of nations. Peoples of the whole earth are trying to decide which is the best political system—democracy or communism. Many nations have already chosen sides and those which have not are torn with internal turmoil in trying to make a decision.

This great conflict coming at a time when some parts of the earth are overpopulated magnifies the importance of the ultimate outcome. In many of the more densely populated sections it is no longer possible to provide adequate food, clothing, and shelter by means of the native agricultural and manufacturing procedures. Such areas of world population look with envy upon the abundance of everything enjoyed in the United States. If such areas can be helped toward our level of living, they will follow our pattern. If not, they will join hands with the enemy and try to pull us down.

Our Task as a Nation

What then is our general task as a nation? There seems to be no other course than to follow our government's proposals to help other people to solve their problems but at the same time keep our nation strong enough to beat down any group which wants to shape the future by force of arms. Civil engineering education has an important role in this world drama. Both foreign and American civil engineers must be trained to have the breadth of social knowledge and technical excellence to transfer American know-how in civil engineering to underdeveloped countries. This must be done in a period much shorter than the 150 years of our own industrial evolution, and without causing serious social and economic maladjustment among the peoples of the earth.

Engineering leaders are needed who are also good economists, others who are also good sociologists, and others who are also good statesmen. Too few of our Civil Engineering graduates have a broad enough foundation to support a career in important international relations requiring extensive knowledge and training in these subjects. In fact not many engineering schools have faculties completely competent to impart such an educational foundation to students. The 20 per cent of humanistic studies so widely accepted is only a start toward what is needed. Some of our best students and staff members should pursue graduate study and aim at engineering statesmanship as a goal.

* Presented before the Educational Policy Section of the Civil Engineering Division ASEE, Annual Meeting, Michigan State College, June 1951.

Need for Specialists

For this world wide job of regional development we also need more specialists with great depth of knowledge in certain fields. Men who can locate the mineral, land, and water resources, others who can plan extensive transportation systems, others who know how to plan, build, and expand cities and still keep them safe against traffic accidents and disease. Other are needed to irrigate the deserts, others who know about flood protection, others who can wring out the last useless pound of dead weight from structures and so on. Graduate study at a university seems to be the most economical way to provide these specialists. After our graduates leave college most of them continue to grow but this growth in most cases is limited by the strength of the mathematical and scientific foundation which they received in college. It is not so difficult for engineers to keep abreast in fields which do not require high ability in the application of mathematics but even in such fields the schools are important centers for improvement and advancement at accelerated rates. It should also be pointed out that in nearly all engineering fields, advances soon carry us into considerations involving mathematics, physics, or chemistry. The civil engineering schools, associated with their respective universities, can provide the best environment for these urgently needed research advances. We have the long-haired scientists and also bright eager young men. Both are needed in our research teams. The civil engineering schools should push vigorously forward on research and graduate work in order to increase the number of top quality engineering scientists which our foreign program and national security demand.

Our output of engineering graduates will be about 15,000 per year for the next several years and at the present rate about 10 per cent of these men pursue graduate work. When one compares this output to the estimated 30,000 engineers per year produced by Russia with a level of training equal to the M.S. degree, the need for maximum utilization of our manpower is emphasized. If we have only one to every two of the enemy our techniques and methods will have to be enough better to magnify our efforts by two. More research will certainly be needed in order to offset quantity with quality.

So far our attention has been focused upon the need for engineers who can serve in an international capacity. The foreign students trained here will supply part of this need but some of our American-born graduates will also be required. By far the biggest demand for American-born graduates will be in the U. S. itself. During the entire struggle between the democratic and communistic systems for world leadership, the United States must remain so strong as to discourage conquest by force of arms. If such a conquest should be attempted we will have to be able to subdue the aggressor.

The work of civil engineers provides the environment for the nation's people. Structures, roads, factories, homes, cities, water supplies, sewer systems, irrigation projects, regulated rivers, and parks are some of our products. The life and comfort of the people at large are in our hands. Our work if well done will increase our national efficiency. If there was ever a time when national efficiency was needed, it is now. We are now short of engineers and to do our job within the United States we need many more graduates.

Our Duties as Administrators

What then are our specific duties in the near future as administrators of civil engineering schools? The following are given as suggestions for discussion:

1. Do all in our power to keep the flow of engineers coming. Do not let our extra efforts disrupt going school organizations. Try to increase the number of freshmen admitted and try to keep sufficient staff members to maintain our schools in healthy condition.

2. Take every opportunity to expand the training and experience of our staff.

Civil engineering education has become somewhat traditional and the pace of our advance needs acceleration if we are to produce the engineering statesmen and engineering scientists called for by our times. To meet this need a substantial improvement in staff quality is needed.

3. Shift our outlook from a national basis to a worldwide basis. We are not building empires but new frontiers have opened in every underdeveloped country. The development of deserts, jungles, and natural resources for a rapidly expanding world population has added many new geographical frontiers.

4. Push forward in graduate work and research. Each school should survey its opportunities for advanced work. Do not be too frightened of false starts. The good old law of supply and demand will eliminate such starts after a fair trial. We do nothing unless we risk a start. Do not be too discouraged by a few failures. The process of trial and error is at the roots of all that makes America great.

5. In short, our future job is to prepare for the tasks of world leadership which events of the immediate past have thrust upon us. The intensiveness of the present "battle for men's minds" will not permit a leisurely preparation. There is no time to be wasted.

In the News

The Fourth Annual Oak Ridge Summer Symposium, scheduled for August 25–29, 1952, will be sub-titled "The Role of Atomic Energy in Agricultural Research."

As contemplated, a number of sessions will be devoted to plant and animal studies with atomic energy research tools. Other lectures will deal specifically with Carbon-14 studies in both plants and animals.

The symposium is being given by the Oak Ridge Institute of Nuclear Studies and the Oak Ridge National Laboratory under the sponsorship of the University of Tennessee-Atomic Energy Commission Agricultural Research Program.

Additional information may be obtained from the University Relations Division of the Institute, P. O. Box 117, Oak Ridge, Tenn.

Dr. Raymond John Seeger, formerly Chief of the Aeroballistics Research Department of Ordnance Laboratory at White Oak Maryland, has been appointed to the staff of the Division of Mathematical, Physical and Engineering Sciences of the **National Science Foundation.**

The Future Prospects of Improved Preparation for College

By C. E. MacDONALD

Superintendent, East Lansing Public Schools, E. Lansing, Mich.

Proper guidance in high school, and even in earlier years, can have a great deal to do with the high school preparation of prospective engineering students. I am happy that we are thinking of this as a guidance process rather than one of selection. The objective is not the elimination of the unfit. The objective is to guide into the engineering field those who belong there because of ability to absorb and make use of certain types of information; because they possess the necessary personal qualities; and because, above all else, they have a very real interest in the engineering profession.

We must be very careful about ruling out prospective engineers, particularly on the basis of subject grades or standardized test results. Technical competence is surely required of the engineer, but let us not be too certain that high academic grades and high test scores assure technical competence in the engineer. On the other hand, let us be equally careful concerning low academic grades and low testing scores. They do not always mean low ability.

I recently came across an article written by Harvey Zorbaugh, Director, Counseling Center for Gifted Children, New York University, in which he points out the dangers inherent in the belief that we can spot people of promise while they are still in school by their grades and their scores on I.Q. or aptitude tests. He feels that there is real danger in the extent to which this belief is being accepted in our national life.

Experience points out that many individuals possess, or later develop, other talents and qualities, such as ambition, drive, leadership, character, and the faculty of working well with other people, which cause them to be outstandingly successful. Henry Ford II failed in his Yale engineering course. Subsequent events proved this to indicate a lack of interest at that time, rather than a lack of ability. Charles E. Wilson of General Electric never finished high school. One could cite such cases almost endlessly.

Several great dangers exist in using grades and test scores as the primary basis to be used in guiding high school youth into the field of engineering:

1. Low grades may indicate lack of interest rather than lack of ability.
2. Poor teaching and low motivation can acount for lack of interest.
3. Outside factors can affect examination and test scores.
4. High academic ability does not of itself assure success in the engineering field.
5. Many gifted men have shown little indication of their ability in school.

Guidance Program

No doubt I am taking too much time to say things which have already been said. But what I have said about guidance indicates a great deal for our high school preparatory program. One might say that there are three vital parts of a program. They are:

1. Guiding young people. This involves use of all available data; and creating an interest on the part of qualified students.

2. The program itself. What are the objectives of the program? What are the possibilities in each individual school's program?
3. The program in operation. Is it well carried out? How may performance be improved?

A high school guidance program for prospective engineers has been very ably presented. My concern is that we use a broad basis in guiding students into engineering; that we be very reluctant to say, "You are not qualified."

I hope, also, that we have a broad point of view concerning our preparatory program. Nobody thinks more highly of technical competence than I. There is no question in my mind concerning the need for mastery of the subject matter of the field. One must have tools with which to work.

Individual schools will vary greatly concerning the extent of the information they are competent to handle. Teachers vary in knowledge and ability. Schools vary in scope of instructional materials. People responsible for planning vary in vision. The small school is likely to be at a disadvantage in regard to courses that can be offered.

This is indicated in a recent publication of the Bureau of School Services, University of Michigan. It is entitled "Program of Studies of 176 Michigan North Central Secondary Schools."

Variations in Science Units

Let us look at the science units offered in these schools. Three and four are average. I presume that this means Biology, Physics, and Chemistry, and General Science, in addition, when four units are offered. However, we find approved schools offering but one or two units in science. At the other end of the scale, we find schools offering as high as eight units. We can readily observe the great variation in the amount of information offered.

Strangely enough, there is considerable variation even in schools of comparable size serving the same types of areas.

In the field of mathematics, the same story is told. Just considering our high schools with over one thousand enrollment, we find a range of from three to ten units in mathematics offered. A number of the small high schools offer as few as two units in the field of mathematics, presumably algebra and geometry.

It seems obvious that many high schools might well give attention to basic offerings in science and mathematics. But the road is not easy. Our state department of public instruction has long advocated consolidation of small school districts, so that richer school programs might be offered. More financial resources would enable a district to provide necessary facilities, and to pay the necessary salaries to attract competent instructors.

But take the large high school backed by a well-to-do school district. How explain the meager offerings sometimes found in these schools? Obviously the students are not asking for extensive preparation in science and mathematics, the fields we are considering. Why? Very likely because they see no need for them. Possibly a strong guidance program could awaken them to the great possibilities they are overlooking. Doubtless many strong prospective engineers are being overlooked. Also, students are probably avoiding these courses because of the way they are being taught. If the procedure is to assign the learning of facts and information, unrelated to any vital student concern, it is not surprising that they stay away in droves. I shall have more to say later about the effectiveness of our teaching.

Mastery of Fundamentals Necessary

My conclusion would be that all schools should concentrate on mastery of the fundamental principles of mathematics and science in the high school years, and then offer such advanced courses in the field as facilities permit. At least one over-all unit concerning itself with the

various engineering fields might well be offered.

We want professional competence in our engineers. Certainly we all agree. But what else? General Somervell says that the second thing that the engineer must be able to do is to "take his place in the organization that he joins." He must be able to get along with other people. If he is to go very far in his chosen profession, he must also be able to handle people. I doubt that many of our high schools have spent sufficient thought on ways of preparing engineers to develop, or helping them to develop, this greatly needed ability. I suspect that many engineering schools have done less.

The engineer must understand the economics of our life. He must be acquainted with general principles of Business Administration. In most high schools this probably means the course in economics as preparation for further courses.

Engineers do not live in a vacuum. They need common abilities that we try to develop to the extent of each individual's abilities. Engineers need to be competent in communication skills. They, as much as any, need to know our history and traditions. Engineers require some cultural background if they are to live fully. Engineers share the responsibility of all to play some part in improving their community, their state, their nation, their world.

Since these are common skills, the high school seeks to prepare all in regard to them. But let us not fail to see them as necessities in preparing the engineer, among the others.

There is, assuredly, plenty of room for improvement in our high school programs for preparing prospective engineers. We must, first, give the student all the personal development possible. This is true in the cases of all of our students. The schools exist primarily to do their utmost to prepare people for living, for citizenship—whether it be as engineers, doctors, lawyers, writers, farmers, secretaries, laborers, or housewives. It is the schools' second function to guide young people into a suitable life work, and to do all possible to prepare them for that life work.

Hope for Advancement

One of the greatest hopes for advancement in the content of our preparatory course lies in the ability of high schools and professional schools to get together in planning the objectives and developing the material for the courses.

In Michigan our College Agreement Plan has found a means of high school and university and college coming together to plan for the common good of the student. It has already resulted in changes in high school programs. I even know instances where it has resulted in program changing on the higher levels of education.

Perhaps the greatest future prospects of improved preparation for college are contained in the third step I mentioned. That is, the actual operation of the instructional program of the high school. We can reach agreement on the objectives of our guidance program and how it is to function. We can, possibly, reach agreement on the objectives of our preparatory program and how it should be set up.

But when it comes to operating these programs, we are dependent upon teaching. The best of programs will be ineffective in some hands. Basically, the improvement in preparatory courses must come through improved instruction.

The first step in good instruction is to arouse interest. Students do not learn and retain knowledge without motivation. If we content ourselves with motivating students by telling them that they must absorb such and such information to become good engineers, we shall make no progress toward improving our preparatory courses. If, on the other hand, we use the problem-solving technique in teaching, we shall draw the students into a challenging situation. They will be interested because they have a part in defining the problem; suggesting solutions; examining the suggestions by means of the

subject matter of the field; and in further observation and experiment leading to acceptance or rejection of the solution. In short, we must make our preparation much more realistic.

I suppose what I have just outlined constitutes the "engineering method." What I am saying is that we should use this teaching approach to interest our students in the subject matter, and to discover the students capable of using the engineering approach to problems.

In my opinion, our preparatory programs for engineering students are weak in that we stress the acquiring of subject matter above the development of the ability to attack problems in a logical manner. We confuse the ability to read, to listen and retain, with the ability to think. Subject matter may always be looked up. There is no place to turn to look up information that may be substituted for the lack of ability to attack a problem.

Abandon subject matter? Of course not. But let us make use of it to stimulate the imagination of our prospective engineers; to arouse their curiosity; and to develop their analytical ability. And let us not forget that the engineer needs to develop common qualities essential to successful living for any of us.

I sincerely believe that we can improve our high school preparatory courses through:

1. Better guidance practices.
2. Improved offerings concerning the subject matter of the field.
3. Setting up as our objective the developing of imagination, curiosity, and logical thinking processes. Using the subject matter as a means of attaining these ends.

This will call for improved facilities and improved teaching. As a school administrator, I regard it as my responsibility to try to create a school situation, a school atmosphere, in which these things can happen.

College Notes

A three-day Conference on Soil Stabilization will be held at the **Massachusetts Institute of Technology** from June 18 to June 20 to examine current problems in stabilization treatment.

Baldwin-Lima-Hamilton Corporation has completed installation of a 600,000-lb. testing machine in the new Structures Laboratory for Civil Engineering and Engineering Mechanics at **Purdue University.** It is a part of a modernization project that will ultimately cost about $3,500,000.

A special program in Infrared Spectroscopy will be given from June 16 to June 27 during the 1952 Summer Session at the **Massachusetts Institute of Technology.**

George F. Carrier has been named Gordon McKay Professor of Mechanical Engineering in **Harvard University.** He is now at Brown University, where his work has been in applied mechanics, especially in fundamental problems in elasticity and fluid mechanics.

Economics and Engineering Economy

Their Relationships and Their Value to Engineers*

By BILLY E. GOETZ †

Professor of Business Administration, Antioch College

Eleven years ago I spoke to the Engineering Economy Section on the use of economic logic by engineers confronted with problems of engineering economy.‡ Today I want to discuss some broad areas of greatly increased importance in which economics can contribute data as well as logic to the engineer's attack on such problems.

Many, if not nearly all, of managements' problems of policy formulation, of choice of resources, of product design, of organizational planning, and of selection of methods and procedures can be subsumed under the classic question of engineering economy—will it pay? In approaching such problems today, the manager and the engineer find the factors to be considered so changed in content and in relative importance as to make his world rather new, strange, and somewhat forbidding. Most of these new, or newly important, factors have arisen within the areas studied by economists. Consequently, economics has a new and somewhat different contribution to make to engineers and managers struggling with "will it pay" problems. Since nothing is really new, we will find that some of these factors have been around a long time, but recognition of their importance has been delayed, and they have not yet been adequately worked into the literature of engineering economy.

How will creeping (or is it faster than that?) inflation affect the relative desirabilities of alternate programs? How do taxes, present and prospective, affect choices among rival plans? How do governmental regulations, current and anticipated, change the terms of engineering economy problems? These questions are conspicuous by their absence in the literature of engineering economy, and by their omnipresence and dominating quality in the thinking of managements. Economists have spent much time and written many articles and books on these subjects.

The Effect of Inflation

First, what does inflation do to engineering economy problems? Obviously, a persistent inflationary trend tends to cause a shift in time preferences. Buyers tend to anticipate their needs. They build bigger, and stock larger inventories, because later things will cost more. Perhaps this can be taken into account merely by changing the rate of interest used in the compound interest formulas by means of which time preferences are so elaborately woven through engineering economy studies. Such an attempt runs into a curious dilemma. If inflation becomes much more pronounced, managers may be willing to pay exceptionally high interest rates to get money with which to buy goods in anticipation of continued violently increasing prices. But exceptionally high interest rates in the compound interest formulas tend to give answers favoring postponement of expenditures. Evidently the formulas contain an implicit assumption of constant price levels.

In times of inflation, managerial at-

* Presented before Engineering Economy Committee, June 27, at Lansing, Mich.

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‡ "The Relationship of Cost Accounting and Engineering Economy," *Journal of Engineering Education*, April, 1941.

titudes toward borrowing and investment change. Capital outlays at present prices can save labor—can reduce labor hours—in the future when wage rates will be still higher. By spending on one price level, future savings on a higher price level may be obtained. Moreover, high taxes make growth by plowing back of earnings difficult; accelerated depreciation makes possible tax savings; and renegotiation encourages the accumulation of secret reserves. All this tends to make managements more willing to finance expansion out of borrowing. After all, if a management borrows $100,000 to increase its inventory (speculation?), and if the price rises by 12% in one year, why should such a management balk at an increase in interest rates from 4% to 5%, 6% or even 10%? But, if the compound interest formulas are to give such answers, the interest rate used will have to be much smaller! If the flight from the dollar reaches the stage of galloping inflation, the interest rate used in compound-interest, engineering-economy studies may have to approach the vanishing point. This means the interest rate used in such calculations can have no relation to actual interest rates or to interest rates managers are willing to pay to get money to spend now rather than later.

Such considerations indicate the need for adjustments of historical cost data. To solve a problem in engineering economy correctly, the engineer must turn prophet; he must predict prices. Economics can help him define his problem, to understand its nature, and to solve it. What is the outlook for more inflation? An increasing population tends to produce and to consume more goods, and the supply of money will have to be increased or prices will fall. Increasing productivity per man hour increases the supply of goods to be exchanged by means of the available supply of circulating medium. This, too, indicates a need for a gradual increase in money and bank credit to avoid price declines. On the other hand, government deficits increase the supply of money and, through the way in which they are financed through the banks, tend to increase the supply of bank deposits. So far at least, the Federal Government has found no difficulty in increasing the supply of money and credit fast enough to keep pace with a growing population and an improving technology! Nor does it seem likely that this state of affairs will change soon. Taxes have grown so great, and impinge on so large a part of the voting population, that politicians are reluctant to increase them further. But war and preparation for war, the welfare state, the welter of private interests seeking subsidies, and the general decline in the efficiency of a top-heavy and rapidly growing federal bureaucracy seem to guarantee ever-increasing governmental expenditures. Further inflation seems almost guaranteed for the foreseeable future.

The Impact of Taxes

Secondly, what does our amazing tax structure do to engineering economy problems? With the Federal Government taking almost two-thirds of the profits of business in the income tax alone (including surtax), and coming back for a second helping of from around 20% to as high as 90% of the remaining third when the business pays dividends, taxes have become a major expense item rivaling materials and wages. Managements show a strong preference for expenditures that can be deducted in computing profits on which taxes must be paid. The consulting engineers and the advertising fraternity have made a bonanza of this preference. Their services score as expenses and are currently deductible. Benefits obtained presumably continue far into the future—they are real assets, secret reserves. If an engineering study and a new machine involve equal outlays and offer equal savings, the deductibility feature of the engineering study gives it the manager's preference.

Another aspect of taxes and contract renegotiations that produce an Alice in Wonderland world for the engineer bent on doing for $1 what others do for $2 is

the attitude of managements spending "4¢ dollars." On a consulting job, I tried to get priority for my project by pointing to its cost in consultant fees. "Let's get it done as quickly and as economically as possible," I urged. "Why?" said the manager, "You're deductible. 80% of our business is on war contract where we will be renegotiated down to a profit of around 10% on sales. On that 80%, you don't cost us a thing. On the remaining 20%, we are in the 80% tax bracket, so the government pays 16% and we pay 4%. When we pay your bill, we are spending 4¢ dollars."

Where does this take us? One task that interfered with progress on the consulting job just mentioned was a renegotiation. In the middle of a war, with dreadful urgency for production, the six top executives of this war contractor, and their management consultant, took three days off to write a brief objecting to the profit allowed by a preliminary hearing officer. We took three days off from war, our costs were themselves deductible and therefore came out of the government's share of the company's profits; and in those three days, eight men earned as much money as the 1500 employees of that company earned in a whole year! We got the appeal board to double the % profit allowed. Of course, the government got 80% of this extra profit back under the regular income taxes instead of getting the whole of it by renegotiation.

Other queer things happen to economy studies because of the incidence of taxation. An economy study shows it to be desirable to get rid of ancient machinery. A tax study shows that it had better be kept until a year of greater profits arrives when the deduction will be more useful. Naturally the tax study takes precedence over the engineering economy study. It is dealing with more important factors! Of course, if the economy study went into the comparison of alternatives as far as it should, it would include all the tax computations, and its answers would then turn out to be the right ones.

Governmental Regulation

Thirdly, what does governmental regulation do to engineering economy studies? Obviously, it sets limits to the available alternatives. Copper may be cheaper, or better, but it may also be restricted. Hiring more labor may pay so handsomely that we are willing to raise wages substantially to get the extra men; but a government board may forbid such conduct. We may want to expand our plant facilities, but be unable to get a certificate of necessity which would enable us to do so. We may be pushed into suspending production of our cheaper lines because the government has frozen all prices and we get larger profits from our more expensive products.

Here, again, economics not only helps define the problem. It also supplies a basis for forecasting. All products, and all resources, are interrelated through an amazing network of prices. General movements—rising or falling average prices—depend upon general fiscal factors such as were discussed under inflation above. But within such general movements there are many eddies. Some prices move much farther than the average, others move counter to movements in the general price level. And some prices are much more closely related than others.

First, there are derived demands, demands passed on from one stage of the production process to a preceding stage. Thus, the consumer demand for automobiles becomes in turn a derived demand for steel. Whatever happens to the price of steel tends to be reflected in what happens to the price of automobiles, and vice versa. By noting such economic relationships, and watching for the first changes, subsequent changes can often be foretold with some accuracy.

There are joint demands; demands for products used together: shingles and shingle nails, automobile carburetors and windshields. When a glass factory in Pittsburgh shut down, an automobile factory in Detroit soon ran out of windshields and shut down its assembly lines. Soon

its inventory of carburetors piled up and compelled it to defer delivery schedules, which it turn soon closed a carburetor factory in South Bend. In general, an increase in price of one item in a jointly demanded group tends to raise the price of the group, which tends to reduce the quantities purchased, which tends to force down the prices of the other components of the group. This is obviously something quite different from the general ups and downs of the price cycle, and not controllable by the fiscal policies of the federal government.

Similarly, there are joint supplies; e.g., byproducts. An increase in the price of one of the joint products tends to increase the quantity produced, and the increase in quantity of the other joint products tends to depress their prices.

There are rival demands. When war industries bid up the prices of steel, copper, wool, etc., the competing users must raise their offers or do without.

And there are rival supplies. Kellogg's Cornflakes and Post Toasties, to take commodities from this neighborhood, are rather close rival supplies. Different breakfast foods are more distant competitors. Other foods represent interindustry competition one more step removed. Finally, all foods compete with other consumers' goods. It is alleged that stenographers on Wall Street or on La-Salle Street starve themselves in order to save money to buy clothes, and perhaps incidentally to fit the clothes they want to wear.

These interrelationships may help in predicting many changes of governmental policies and regulations. For example, if price controls succeed in holding down or lowering prices, we know from theoretical considerations that quantities demanded will exceed quantities supplied. Either rationing will be necessary, or the commodity will largely disappear from the market. This, of course, leads to much waste of time standing in queues. Nor do the strong pronouncements of a practical-politician price controller change this matter one iota.

Furthermore, black markets are bound to appear whenever the difference between the official price and the black market price is sufficient to absorb the costs of evading law enforcement. And this is true of smuggling, and of moonshining, as well as of the black market.

Rival supply considerations should warn a price controller that fixing a price on one commodity almost insures the necessity of controlling the price and rationing the supply of all close substitutes. Almost any price fixing and rationing tend to reach out through joint demands and supplies, derived demands, and rival demands and supplies to more and more commodities until virtually all important commodities must come under the price fixing code, with rationing to match.

Finally, the theory of inflation should warn price controllers of the need to reduce inflationary pressures if official prices are to remain close enough to free prices to make black marketing too costly for so narrow a gross margin.

Summary and Conclusion

To summarize and conclude; inflation, taxation, and governmental regulations are newly important factors in many managerial problems of choosing from among alternate policies, product designs, production methods, or productive agents. These factors are now neglected in the literature of engineering economy, but not by economists nor by managers. If the engineer continues to ignore them, he must reconcile himself to seeing his reports filed in the round file; he must reconcile himself to wasting time and money producing reports of little value. Probably problem solving is becoming a matter for teams comprising a variety of specialist experts: an engineer, a tax accountant, an economist, a lawyer, and God knows what next! But these experts must establish effective communication among themselves or the teams cannot function. That means each must have considerable understanding of the problems, the terminology, and the techniques of the others.

How the Library Can Serve Engineering Students*

By JOHN H. MORIARTY
Director of Libraries, Purdue University

Among American people with schooling, the presence and use of library facilities are so taken for granted that their nature is not often considered. The purpose of this presentation is to try to jolt you into taking a fresh look at your library and the use that you and your students make of it.

The Library as Machine

Basically your libraries are machines for serving up books, just as houses are machines for living and cafeterias are machines for eating. To the gentle humanist this has a sacrilegious tone. He feels the library is the heart of the campus or the treasury of man's spiritual life. He probably also thinks of the moon as the queen of the night, rather than a satellite of the earth, 238,840 miles distant. But the astronomer and the librarian have to take the materialistic attitude, and the approach to the library as a machine has very real values.

A second important concept, not often faced by even the librarians, is that the American library is normally a self-service machine. Consider your own library experiences. As a little tot you went into the children's room of your local Carnegie Library and pulled the easy books off the sloping tables; as a young adult you used your high school or public library shelves. In college, you went into the library, spotted the ABC catalog, made out a slip, passed it without a necessary word to a dead-pan clerk and received either your book or checked notice describing its absence from shelf. It was and is all just as mechanical as that. And being American and democratic and used to fending for yourself, you probably really like it that way. I was talking of this to a friend of mine, a columnist on a large midwestern paper. He told me a story on himself, about a use he made of a city library. At 60 years old and the father of a 35 year old son, he remarried. The lady was in her forties and a pleasant companionship was anticipated. Instead at 62 he found he was to become a father again. He was mad at the very idea and disregarded the whole affair as much as he could. On the birthday he assured himself only of his wife's satisfactory condition and let the matter drop. After about three days, on a visit to his wife it dawned upon him that he didn't know the baby's sex. The more he thought of it the more aghast he became. He listened to his wife's talk to the nurse, to the doctor. All of them maddeningly referred to the baby or the child. He left the hospital terrified lest he meet one of his friends and be forced to reveal his indifference, which he now saw was sheer evil. Being an old newsman he headed for a newspaper office but found it was so late that the back issues room was closed. He was standing bewildered in the street when suddenly he realized he was in front of the Public Library. He had it, it was solved. In he hurried and got in line to wait for a paper. "And," he said to me, "if one of you snoopy librarians had asked

* Delivered at a conference of English Division at the ASEE Annual Meeting at East Lansing.

me why I was there, I'd have knocked you down."

But this realization of the library as a self-service machine puts upon the user and the librarian certain very specific responsibilities if the educational effect of the communication potential in libraries is to serve the user for his betterment. This paper is to lay out before you one special corner of this big problem, namely certain peculiar responsibilities of the engineering teacher and engineering librarian within the general situation.

Redesign of Library Service

The standard practice in getting a machine for self-service into general use is to make a market survey of the potential customers and their peculiar problems and to design the machine to take into account these findings, and this, of course, in addition to the regular laws of mechanics which it must obey. And once you have done so, then you institute a sales campaign to educate the public to handle and exploit the machine. The telephone industry illustrates pretty well what I am describing.

What has happened to the marketing of the library as a self-service machine for engineering education is a sad, sad example of how—in any economic world—to go bankrupt in a hurry. No fundamental study of the nature of engineering use of documentation has ever been made. The engineers are not naturally subjective; the librarians have not left off tending the machines long enough to study their effect. As President Edward C. Elliott of Purdue once thundered at me: "The trouble with you librarians is that you don't know what your libraries do to people's minds!" And he was right. What we have done, for lack of basic research, is to improvise and patch. And I for one am tired of worrying about the bare backsides of engineering education which shows through the patches and I'm going to ask you to look at them with me, hoping some of you can figure out how to stretch and mend what we have to make a better fit for our needs.

Break between Classroom and Library

The sharp gap between the classroom and the library is one big hole in our educational front. The path to our present situation goes back some fifty years or so. Up to 1900, the small college library was usually a side or extra job for some professor. At Purdue University at that time the Registrar was librarian too. But at the turn of the century a crisis was reached. Printing presses, based on new printing technology, began to roll; Science and especially the Social Sciences began to record reams of data never before put down—for example the U. S. census of 1870 occupies *one foot of shelf*; for 1880 the census volumes cover *six feet of shelf*. The poor professors, registrars, deans, began pounding on college presidents' desks, demanding relief, help with the mess. They got it; young women trained in library techniques took over, tidied up the mess in a few years, to the intense relief of the administrators. In the administrative relief, nobody stopped to consider that the contact with the teachers and the class room problems and the relations of classroom to library usage, were sacrificed. They were sacrificed, and as libraries grew in size, the break between classroom and library widened.

Now, let me reiterate that nobody was malicious or willfully withholding help or service. All were caught up in a social problem. Libraries, like it or not, were turned into machines I have described. The huge bulk of literature demanded machine precision in handling. Its growth was so rapid as a social phenomenon that the size of library staffs never got to match it or secure even complete mechanical coverage of the material pouring in (the Library of Congress has a backlog of 1,250,000 magazine issues unrecorded. The Nuremburg War Criminal Trial Records, which occupied a full carload going from the ship in New York to Washington, naturally haven't yet been organized). And the presses roll.

Now the best minds in our field of librarianship are naturally in these large

research libraries. If they are overwhelmingly pre-occupied with the raw and material problems of physical control, who is left to consider human use and service of this material on a high plane? Certainly the young girls who come into the library field for two years, five years and then leave really never catch the vision at all.

And there would be some hope for our problems if readers who use the library were more critical.

But most Americans are too active to be really bookish people or to haunt libraries and when occasionally they do venture into the beautiful mausoleums of our large campuses and cities or into the department store type library in the small towns, the average American has a sort of lost feeling. Take the poor student who's been told to write a theme of his own choice. He wanders from shelf to shelf; he toys with the catalog, and finally, he sidles up to the janitor or charlady and says almost off the side of his mouth, "You got anything here on rockets?" And when his teacher does send him to find some one thing, the situation often isn't any better. I'll cite an actual case. A student caught me on the run one day and said Prof. M. wanted him to read a biography of Roger Williams by Vernon Parrington and had said that the Library did have it. He counldn't find it. Well, I did know that Vernon Parrington's death twenty some years ago at an early age with his great work entitled "Main Currents of American Thought" still unfinished is a prime intellectual loss to our country and that Parrington had written too little else. I felt that if he had done a Roger Williams biography, it would be a valuable item on Williams. So I went and looked in the *Dictionary of American Biography* under Williams and in the list of works about Williams, I found Parrington listed not as a biographer but with the reference to Volume I of the "Main Currents" which has the separate title "The Colonial Mind" and has about 100 pages on Williams. This was obviously the biography meant by Prof. M., but how a boy of 19 was supposed to find it with what research skill he had, I confess I do not know.

I do know that there is a bad gap between what orientation to further study is given to students in the class room and the situation they face when they walk into the library. And I know that everyone of you people has as a student faced that too.

Engineering School Library

The gap between classroom and library that I have so far described would be as true of a liberal university as of an engineering school. The engineering school library has all such general weaknesses because as the professional engineering school has developed there has been merely a transfer to it of the library practice used for the humanists and the social scientists, with hardly a thought that an engineering school would require anything peculiar by way of documentation service. The engineering faculties certainly didn't ask for anything different. What they and their students have done is simply to stay away from the libraries. In its way, this absence can be as bitter a complaint as can be lodged.

Library Absenteeism

What was and is back of this library absenteeism? The students stay away because the engineering faculty do not send them to the library. The engineering faculty do not send them to the library because it has been the nature of technical men when pursing knowledge to enquire first personally of someone else who may know. Next, they will test a hunch of theirs in the laboratory. And finally and only finally will they try consultation of the literature, which has seemed to them the least desirable. So you see, the engineering faculty has not sent students to the library because the faculty, following

its two favorite methods, personal exchange between student and instructor and laboratory work, has felt these are enough for all ordinary undergraduates. The ordinary engineering undergraduate has agreed heartily.

The undergraduate's main use of the engineering school library has been generally forced upon him by his non-technical electives. His instructors in English, Speech, etc. are usually the ones who send him to the library and thus all too often, as by a vicious followup punch, he comes to see the written record as having little to do with his major interest, engineering.

Why do I say "vicious"? Is this just because I am a librarian and want more customers? No, it is not; though I won't pretend to disinterest. I feel it is vicious because it imposes a habit toward knowledge that sets a young engineer's career back anywhere from five to ten years.

One glaring fault with all this engineering school picture is the almost total failure to teach the regular reading of technical journals as a device of professional education, particularly of professional self-education.

You all know that no active professional or business man can keep up today who does not read through at least two professional or trade journals a month. The technologies, more even than other fields, are documented almost completely by the journal article. This is a phenomenon of the last fifty years and in many ways our educators do not yet face its meaning. And by this I indict the librarians equally if not more than the engineering or other faculties. We have acted as though the journals were step-children. We solemnly buy, . . . new, texts and monographs with data that are anywhere from two to five years obsolescent. We have spent cataloging and shelving costs on as many as fifteen copies of a textbook, when if an instructor had wanted fifteen subscriptions to one journal for a class we would have gone hot-foot to a dean or president to have that man stopped. We buy one subscription, guard each issue fiercely to prevent any loss of numbers, bind them up promptly, and refuse then to circulate the bound volume. I confess all this because I feel just as apologetic for library practices which prevent students' education as many an engineering teacher has told me he felt about his students' faliure to learn to use the literature.

Engineering Documentation: Now and Later

As engineering education in our expanding technology becomes more and more an introduction to fundamentals and less and less an exercise in current practice, the student needs increasingly a correct orientation toward how he can himself discover current practice. His future experience as a successful engineer facing a new problem will typically be to move (1) from the general awarenes of up-to-date methods which regular reading in his own monthlies such as *Mechanical Engineering* or *Civil Engineering* or some other may give him on to (2) specific journals such as *Materials and Methods* where either articles or advertisements will lead him to (3) catalogs, company handbooks, or direct contact with sales engineers.

This experience is one that every student engineer should have, not once but often enough in his distinctly engineering courses that it becomes for him a set procedure. Beyond this he should have built up by his engineering teachers a literature attitude which is contemporary.

The classic attitude of personal consultation and laboratory testing which I have described above as typical is as of now becoming an old-fashioned and small company or one-engineer-in-the-firm kind of attitude. The larger companies are developing for themselves company libraries sometimes of several thousand volumes. But often these shelves of books may be quite lacking or a bare half dozen. Rather the room will be crowded with filing cases holding engineering reports, clippings, specification sheets, patents, and data sheets of all sorts. The librarian

of such a company will be almost completely receiving, scanning, and abstracting a hundred or more journals which will then be circulated among the engineering or administrative staff.

This is the industrial documentation which our young engineer must face and for which neither academic lecture, laboratory nor library prepares him. By a youngster engineer in a company the right attitude and apt use of such an industrial library can markedly shorten his induction period and give critical boosts in meeting his competition. But the average young engineering graduate is rarely prepared to understand or to exploit such industrial opportunity. Some of the long-standing sorrow over poor report writing might be alleviated if the students could be motivated by an appreciation of American industry's use of the engineering report as industrial documentation and record. Certainly little he sees in academic libraries prepares him for such appreciation.

Ways Out of Our Dilemmas

Now I know many an engineering school librarian will say that no one ever urged him to adjust his library practices so that it will teach students to be at home in an industrial library. And there will be numbers of instructors even of engineering who will see little point to such a set-up spoiling the nice sedate and conventional library to which they are accustomed. Actually too overwhleming a revolution is not required. Industrial firms have often quite handsome libraries. The real revolution is a recognition that the record, the documentation, the literature or what you will has today a part to play in technology's evolution which men trained twenty-five years ago can hardly appreciate. The great industrial firms have set the pace, determined not to infringe patents or duplicate design or work. The librarians however have been no leaders in observing and bringing these new developments into their schools as part of their offerings. But the crust of conservatism is breaking. The engineering faculties are beginning to experiment; the librarians are beginning to bend their practices to fit their users. What then should the progressive engineering school library do for the student? I will close with a brief plea for action on three strategic fronts—the quarters or physical setting, the collection or stock, and the staff.

The quarters, the library rooms, have to be adapted to man, and not demand that man be neurotically quiet, restrained, and unnatural while at study. Small symptoms of such improvement would be the provision for smoking, conversation that didn't distract others, enough space to spread papers, booth-like arrangements giving a sense of privacy, freedom to slip off shoes, drop your head for a nap, and other provisions that would make a man feel at home. Old line librarians will be scandalized at such unseemly public behavior. I'll put up with it and worse if it will contribute one iota to make better prepared engineers. The public polish is a superficial refinement that can and will come later. The library should be a place to study, tailored for men.

As for the collection or books, I have given above the clue to my thinking. Let us haul in the vertical files and beg from industry the raw data of engineering's advances. Why do I stress this? Well, what I want to do is to use the library's materials to motivate our students by the example of live and current applications of the theoretical topics they are studying. A student's inspection of these if astutely timed by his instructor would send the boy back to his thermodynamics text convinced that he'd better have his thermo principles down cold or else. I want to make the wealth and kinds of engineering records a challenge to the student, rather than what the library now is, namely a chore.

And finally the staff has to be looked at. To give the engineering student a break, we'd better get the librarian out of the library at least one-third of the time. At

least that time each week should be spent in faculty consultation. And I don't recommend that the consultation be in the library office. It should be the other way around. The librarian should go out as a salesman to see how the product or service is going over. Only by such a devotion to consumer research and selling can the librarian verify that the library machine is serving its function.

It will be a long time before most of our engineering schools' library service reaches these or comparable goals. The problems of inadequate quarters, inadequate collections, inadequate librarians are real and very human problems. In dealing with these real and human problems, John Dewey has wise obiter dicta for us: "We don't solve such problems. We outgrow them."

College Notes

The Summer Laboratory Course in Techniques and Applications of the Electron Microscope will be given again this summer from June 16 to June 28, 1952, by the Laboratory of Electron Microscopy in the Department of Engineering Physics at **Cornell University.** The course under the direction of the Dr. Benjamin M. Siegel will have Dr. James Hillier of the RCA Laboratories, Princeton, New Jersey, and Dr. C. E. Hall of M.I.T., Cambridge, Mass., as guest lecturers this year.

The course is designed for those research workers, institutional and industrial, who have recently entered the field of electron microscopy or who are now planning to undertake research problems involving applications of this instrument. Further inquiries should be addressed to Dr. Benjamin M. Siegel, Department of Engineering Physics, Rockefeller Hall, Cornell University, Ithaca, New York.

The appointment of Bernard E. Proctor to Head of the Department of Food Technology at the **Massachusetts Institute of Technology** was announced by George R. Harrison, Dean of Science at the Institute. Proctor, who is Professor of Food Technology and Director of the Samuel Cate Prescott Laboratories of Food Technology at M.I.T., has been acting head of the department since January 1951.

Transportation of Sediment has been chosen as the theme of the Fifth Hydraulics Conference to be held at Iowa City, Iowa, June 9–11, 1952. . This series of triennial conferences is sponsored by the Iowa Institute of Hydraulic Research of the **State University of Iowa.** Topics of the six half-day sessions will include problems of laboratory and field measurement sedimentation in canals, rivers, estuaries, and harbors; and a tour of the Institute laboratories.

Student Evaluation of Teaching Techniques

By HARRY W. CASE

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Introduction

One of the problems that has constantly perplexed educators for a number of years is that of determining the most effective methods of teaching, in terms of learning ease and interest. These two factors undoubtedly significantly influence the rate at which an individual can acquire material presented in a course. As an aid to teachers in formulating their course presentation, the Student-Faculty Evaluation Committee of the American Society for Engineering Education undertook a limited study of teaching techniques during the past year. The problem was approached by undertaking to measure the attitudes of a sample of students toward methods now currently used in the teaching of engineering courses. Unfortunately, the vast array of courses taught in an engineering college and their complexity in terms of content material made it impossible to design a survey for the specific purpose of measuring the most effective method of presentation for a particular subject. Therefore, the survey was designed to cover only the broadest aspects of presentation.

Subjects

The subjects used in the study consisted of some two hundred and nine engineering students divided among six universities—Bradley University, Northwestern University, Ohio University, Pennsylvania State College, the University of California, and the University of Illinois.

The problem was approached by asking members of the Committee to distribute questionnaires to their engineering classes with the request that the students complete the form to the best of their ability. The questionnaire was divided into two parts: the first of which consisted of rating a number of described teaching methods for interest and ease of learning. These were: (1) the uninterrupted lecture, (2) lecture combined with recitation, (3) the entire course based on problem sets, (4) course constructed around student projects, and (5) course including lecture, recitation, problems, and student projects. In the second section provision was made for the student to introduce his own ideas into the evaluation by having him first rate the effectiveness of teaching devices; second, determine the percentage of time that should be allotted for various types of presentation; and third, furnish information concerning the most effective and least effective methods of teaching he had encountered.

Results

If we examine the teaching methods listed in Table I and the relative ratings assigned to them by the students, it is apparent that the more diversified the method of presentation is, the higher it ranks in terms of the students' evaluations. For example, the highest single rating given to any of the listed methods was assigned to the presentation which combines lecture, recitation, problems, and student projects. Following this is the method in which the course is constructed around student projects and the uninterrupted lecture which uses material that is supplemental to the text, both of which rank comparably. Next in ranking is the lecture based on supplemental information combined with recitation, and finally the teaching tech-

TABLE I

	Interest					Learning Ease				
	Excel-lent	Above Aver.	Aver-age	Below Aver.	Poor	Excel-lent	Above Aver.	Aver-	Below Aver.	Poor

TABLE I

	Interest					Learning Ease				
	Excellent	Above Aver.	Average	Below Aver.	Poor	Excellent	Above Aver.	Average	Below Aver.	Poor
Uninterrupted Lecture										
a. The instructor gives an uninterrupted lecture, but deviates little from the content of the text	2%	15%	32%	31%	20%	8%	25%	40%	15%	12%
b. The instructor gives an uninterrupted lecture, but uses material different from but supplemental to the text	22%	43%	25%	8%	2%	13%	38%	37%	8%	4%
c. The instructor gives an uninterrupted lecture, but the material is primarily related to his research and has little to do with the text material	12%	25%	24%	18%	21%	1%	9%	16%	36%	39%
Lecture Combined with Recitation										
a. The instructor gives a lecture deviating little from the text content, but combines this with student recitations	6%	23%	44%	17%	9%	14%	32%	39%	12%	4%
b. The instructor gives a lecture using material that is different from but supplemental to the text, and combines this with student recitations	19%	45%	26%	6%	3%	16%	33%	32%	12%	5%
c. The instructor gives a lecture with material primarily related to his research and having little to do with the text, and combines this with student recitations	7%	20%	29%	23%	21%	2%	5%	22%	41%	30%
Entire Course Based on Problem Sets										
a. The instructor spends the entire period having students place assigned problems with solutions on the board, with little or no comment about each problem	0%	2%	18%	28%	63%	4%	3%	16%	33%	47%
b. The instructor spends the entire period having students place assigned problems with solutions on the board, but gives constructive comments concerning the solutions	7%	24%	37%	23%	8%	10%	31%	36%	21%	3%
c. The instructor spends the entire period having students place assigned problems with solutions on the board, but relates them to the next day's assignment by means of a critical analysis of their solutions	10%	26%	40%	17%	6%	13%	34%	32%	16%	5%
Course Constructed Around Student Projects										
a. Instructor lectures to clarify the scope, techniques, and solution of the project. Students then conduct individual projects and report on them to the class	22%	44%	21%	10%	2%	14%	40%	31%	13%	2%
Course Includes Lecture, Recitation, Problems, and Student Projects										
a. Instructor combines lecture, recitations, problems, and student projects	43%	35%	19%	2%	1%	41%	33%	23%	2%	1%

TABLE II

EFFECTIVENESS OF TEACHING DEVICES

	Most Effective to Least Effective					
	1	2	3	4	5	6
Lecture	41%	25%	20%	8%	4%	3%
Problems	28%	41%	19%	6%	5%	1%
Recitation	5%	17%	25%	25%	15%	13%
Student projects	9%	16%	21%	26%	21%	7%
Film presentations	13%	15%	16%	19%	29%	8%
Other teaching aids	4%	5%	13%	10%	13%	55%

nique in which the entire course is based upon problem sets with little or no comment concerning them.

It will be noted that the students were critical of several lecture techniques. In particular, objections appear to exist to the form of lecture that is related primarily to the instructor's field of research and has little to do with the text. This appears to hold true even though the lecture is broken by recitation. Similarly, although not to the same degree, the technique of simply following the text is considered to be only average. It would be interesting to see whether this technique was preferred by the better or the poorer students.

Analysis of Table I seems to point to the conclusion that the students like problem sets when they are related to the next day's assignments by means of a critical analysis by the instructor. Conversely, they dislike, from the interest and learning ease standpoint, the technique of having problems placed on the board with little or no comment.

The first question in Part II of the questionnaire (Table II) consisted of asking the individual to place a number from 1 to 6 in front of each of six items—1 being the most effective and 6 being the least effective. It will be noted that the students distributed the items in the direct sequence in which they were presented. It is possible that the material was arrayed by chance in the sequence in which the students did select it. However, it must be remembered that the actual arrangement of the items may have influenced their judgment. The second question in Part II read: "Assuming that the total amount of study for any given course equals 100%, how would you distribute the time on a percentage basis for the following activities?" Lecture was assigned 35%, recitation 15%, problem sets

TABLE III

MOST EFFECTIVE METHOD OF TEACHING

(Showing percentage of total students listing the method)

Lecture and problem sets	39%	Lecture and recitation	3%
Straight lecture	18%	Lecture and few problem sets	2%
Straight problems	11%	Projects and problem sets	2%
Projects, lecture, and problems	5%	Lectures and many problems	2%
Lecture and film	5%	Few projects, lecture, and problems	1%
Projects and lecture	4%	Projects, lecture, few problems	.5%
Straight projects	4%	Lecture and laboratory	.5%
All techniques combined	8%	Visual aids alone	.5%

TABLE IV

LEAST EFFECTIVE METHOD OF TEACHING
(Showing percentages of total students listing the method)

Uninterrupted lecture (non-deviating from subject)	22%	Teacher lacks preparation	3%
Lecture entirely on text material	20%	Class lacks participation	3%
No (vague) explanations	8%	All theory, no practical application	3%
Deviation from lecture (much)	8%	Entirely projects	1%
All problems placed on board	6%	Teacher answers questions the entire period	.7%
Entirely problem sets	6%	No homework	.7%
All recitation	5%	Lectures from records	.3%
Problem results not given	5%	Lecture and problem sets	.3%
No problems at all	4%	Lecture and laboratory	.3%
Dull, abstruse lecture	3%		

27%, student projects 13%, other homework 7%, and other 3%—the total equaling 100%. This it should be noted is in general agreement with the other results.

The results to question 3 (Table III) which read: "In my experience and concerning the ease of learning and interest, the most effective method of teaching I have encountered has been—," indicate that lecture and problem sets, straight lecture, and straight problems are the most common selections. It should be noted that in general the information furnished was, unfortunately, not capable of being compiled in the exact form in which it was returned but had to be divided into categories for the purpose of computing percentages.

The question in Part II (Table IV) which read: "In my experience and considering the ease of learning and interest, the least effective method of teaching I have encountered has been—," was answered by the uninterrupted, non-deviating lecture being selected by 22%, and lecture entirely on the text by 20% of the students.

Question 5 of Part II asked whether the

TABLE V

CHARACTERISTICS OF AN OUTSTANDING TEACHER
(Showing the percentages of the total students listing method)

Knows subject	14%	Logical presentation	2%
Good presentation	9%	Available to students	2%
Enthusiasm regarding subject	7%	Organizes material	2%
Understands student	6%	Impartial	2%
Sense of humor	6%	Patient	2%
Good voice	5%	Commands respect	2%
Interested in student problems	5%	No "unrelated" talks	1%
Has personality	5%	Poise	1%
Experience in field taught	4%	Intelligent	1%
Friendly	4%	Fair grader	.8%
Helpful to students	3%	Sincere	.8%
Not egotistical	3%	Good examinations	.7%
Answers questions satisfactorily	3%	Does not lose temper	.5%
Relates subject to life	3%	Strict	.5%
Good appearance	2%	Uses easy terms	.4%
Simplifies ideas	2%	Honest	.1%

most effective or the least effective methods of teaching in their experience were dependent upon the personality of the instructor. To this question 70% indicated yes, 29% indicated no, and 1% qualified it as partly.

The final question of Part II (Table V) asked the students to briefly describe the characteristics that they thought made an outstanding teacher. The most frequent qualities were those related to a knowledge of the subject and the presentation, while the least important items were those related to grading, examinations, and other details of organization.

An examination of the compiled material indicates the impossibility of drawing conclusions that will apply to any one subject. The students' indication of the importance of personality in relationship to the method of teaching should afford clues as to why the assigned rating percentages differ so widely. The survey gives us much to reflect upon when we see, from the students' viewpoint, the undesirability of having an instructor spend the entire period on problems with solutions placed on the board with little or no comment about each problem. From the students' viewpoint there are certain techniques that are more desirable as motivators in the ease with which they enable them to learn the specific material.

However, before we make any generalized conclusions as to the validity and reliability of a study of this nature, it should be pointed out that in the first place this type of study does not afford an indication of the actual knowledge a student will take with him from a course as a result of a specific teaching technique but rather reflects the student's viewpoint of the ease with which he can learn material and the motivation that aids him in acquiring this information. Before even any tentative generalizations can be made concerning the other assumptions, that is, that a student actually acquires a greater amount of knowledge under one technique than under another, it will be necessary to determine the interrelationship of grades to teaching methods.

Conclusions

The following conclusions are tentative and based only on the students' viewpoint and do not necessarily reflect the actual learning that takes place:

1. A course that includes lecture, recitation, problems, and student projects is the most desirable in terms of learning ease and interest.
2. A course in which the instructor uses the entire period for having students place assigned problems with solutions on the board, with little or no comment about each problem, is one of the least desirable techniques.
3. About 35% of the total time involved should be devoted to lecture, about 27% of the total time to problem sets, 15% to recitation, 13% to student projects, 7% to other homework, and about 3% to additional activities.
4. The students believe that the method of teaching, in terms of its effectiveness, is dependent upon the personality of the instructor.

A General Curriculum for Agricultural Engineers*

By L. W. HURLBUT

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The prime responsibility involved in planning for a college education centers in the preparation of students for subsequent continuous development in their chosen field and good community life. Whatever contributes significantly to this end deserves our wholehearted support.

In Agricultural Engineering, we are relating a complex profession to a most complex industry. Yet, there is ample evidence to indicate that we need not lament the fact that there is insufficient time in our undergraduate curriculum for all the "good" courses that could be offered in engineering and/or agriculture. It behooves us to be very selective in preparing a series of well-integrated courses and presenting them with enthusiasm. The curriculum must be planned to develop intellectual maturity for the student with due consideration of time and money involved.

More specifically, our ultimate objective is to produce good Agricultural Engineering graduates in possession of a relatively high degree of intellectual maturity including good fundamental training, an enthusiastic attitude toward their work, and a full confidence in their ability to get the facts necessary to solve problems and get jobs done. A graduate Agricultural Engineer who needs a course before he can attack a new problem lacks in such maturity.

*Presented at the Agricultural Engineering Conference at the Annual Meeting of the ASEE, East Lansing, Michigan, June 28, 1951.

Factors Involved in Planning A General Curriculum

The main factors involved in planning a general engineering curriculum appear to be about the same as those involved in planning any other curriculum. They include the student, the instructor, the course plan, and the primary field of interest during and subsequent to college. The curriculum itself is merely the plan by which the philosophy of the college, the department, or the profession is implemented.

The student brings personality, character, ambition, resourcefulness, and technical ability in varying degrees of development. He commonly selects Agricultural Engineering because of an interest in solving problems of a physical nature and a deep interest in agriculture and rural people. The problems he knows as a pre-engineering student may or may not be those with which the Agricultural Engineer is daily involved—but, nevertheless, past events influence his choice. As a freshman, he may bear some dislike for the requirement that time be spent on courses other than the chosen field. Therefore, one of the first things to be learned is that an engineering education in a democracy must recognize three distinct areas of interest and development. The first area deals with him as an individual; the second with him as a citizen or one of a group of workers; and the third with him as a Professional Engineer. Broad interests generally are not inherent in most high school graduates so it is up to the

college teacher, and the curriculum, to provide for the stimulation of these interests.

Teacher is Important Factor

The teachers will probably rank second in importance to the student and greater in importance than the curriculum. The statement that the teacher is a very important factor in a program of education is well substantiated by interviewers who consistently claim that they can quickly spot student interests paralleling those of the influential instructors. The teachers and their courses in the curriculum must:

1. Transfer the requisite factual information to the student.
2. Develop confidence in his ability to learn; good engineering teaching is generally considered to be the development of the student's ability to do things for himself.
3. Develop the student's confidence in his ability to discriminate among values and make intelligent judgments.
4. Improve his methods of expression through speaking, writing and drawing.
5. Help develop character, personality, and citizenship.

These requirements definitely suggest a general curriculum and good instructors. The ideal instructors for courses in a general curriculum are not easy to find. First of all, they should be scholarly specialists, yet, each have a broad outlook and an engaging personality. They should be skillful and inspiring teachers and have an active interest in public affairs. They should be engaged in research, and have an interest in administrative procedures. They should have industrial or professional practice as a background for selecting practical applications wisely, and presenting practical experiences vividly. It is evident that there must be some compromise with the faculty as well as with the curriculum, but this situation need not alter our aims and ideals.

The curriculum forms the steps toward achievement of intellectual competence and maturity. Three stages of student development can be fairly clearly recognized in the technical part of our general curriculum. In the first stage, the student learns facts. The second stage involves the selection of facts and the fitting of them together into an organized whole. The third stage develops the disciplined ability to discriminate between facts, analyze situations, and basic practice in creative ability—that is, to devise solutions to relatively complex problems.

In a program of such progressive general development, the courses must be arranged in well integrated sequences with each advanced course building on fundamentals already developed. The content of each course must be planned to keep fundamental laws before the student and to provoke the realization that complex problems involve a number of less complex elements. The objective is continuity of experience expressed in the various phases of study.

MINIMUM REQUIREMENTS FOR THE AGRICULTURAL ENGINEERING GROUP (2)

Agriculture and Agricultural Engineering—Agron 53; Agr. Options, 9 hrs; AE 5, 7, 123, 223, 225, 243, 244, 254	41 hours
Mathematics 14, 16, 17, 105, 106, 107	19 hours
General Engineering—EM 1, 2, 3, 4, 121, 225; CE 219; EE 101; Eng. 1, 50, 100	24 hours
Physics 103 and 104	10 hours
Chemistry 3 and 4	6 hours
English Usage—Eng. 3, 4; Speech 111	9 hours
Military or Naval Science	4 hours
Non-Technical Options	15 hours
Technical Options	8 hours
Orientation (freshmen)	0 hours
Total	136 hours

It is important to note that our general curriculum plan suggests that a certain amount of specialization is necessary in order to prepare the student for the

more complex problems. This condition necessitates that judicious compromises be made in developing both broadness in thinking and broadness in subject matter. Broadness in thinking comes in building new elements, through the various phases of Agricultural Engineering, upon the physical sciences, mathematics, basic engineering courses, economics, and humanities. There must also be a proper balance between the applicational and theoretical aspects of the subject matter. It is important to recognize that student engineers are basically intensely practical people and they expect practical features to appear in the college course work. Furthermore, before acquiring a mature status, the new graduate must generally serve some time as a sub-professional and at this level he may be called on to produce in competition with craftsmen from trade schools. Therefore, he must have limited confidence in, and basic practice with, the tools and methods of the craftsman.

The curriculum adopted by our faculty begins the development of broad versatility in the freshman year. The start is made in a course entitled "Introduction to Engineering" presented by Dean R. M. Green and his staff. The course description reads, "Survey of requirements in the various fields of engineering; services performed by Engineers, civic and ethical implications of the practice of engineering, characteristics of the fundamental requirements." Subsequently, the student selects fifteen hours of "non-technical" electives which are at the level of his college standing.

The climax to work in the three areas, aforementioned, comes in Engineering 100, a senior course, again presented by Dean Green and staff. The course description reads, "Professional relations, personal requirements, civic responsibilities and ethical obligations for engineering practice. Legal registration of engineers and architects. Sub-professional and professional services. Changing conditions in engineering practice. Requirements for placement in engineering." The two courses, Engineering 1 and 100, serve as the framework which binds together the three distinct areas.

Broad Versatility is Required by Employers

The employment pattern of Agricultural Engineers shows a very broad use of their talents beyond the professional phases of development and design; and this is an important element to be considered. This consideration is important for other branches of engineering too. For example, a recent report received from the International Harvester Company (1) indicates that in 1890 industry employed one engineer for every 300 other employees, whereas in 1950, one engineer was required for every 69 employees.

An attempt has been made by Martin John Bergen (3) and others in the E. I. du Pont de Nemours and Co., Inc., Newark, Deleware, to evaluate the professional performance of a large number of workers representing the entire field of engineering design. The objective was to determine whether or not a "work" function could be derived from Performance Rating data. The study indicates that eight important variables grouped themselves naturally into two groups—the first group consisted of those factors which were learned primarily by formal schooling, called "Ability and Knowledge" factors. These included:

1. Knowledge.
2. Analytical ability.
3. Ability to learn new duties.
4. Ability to write and speak clearly.

The second group were called the "Psychological and Personality" factors and they were:

1. Cooperation.
2. Initiative and creativeness.
3. Judgment and common sense.
4. Supervisory ability or leadership.

As expected, the various factors were found to be interdependent. It was concluded that in the more responsible posi-

tions the company was paying two dollars for the "Psychological and Personality" factors for every dollar paid for the "Ability and Knowledge" factors. The "Ability and Knowledge" factors presented practically no difficulty because these were the factors that had been specified and for which there was some measure. This study serves well to indicate the importance of the "Psychological and Personality" factors. These latter factors are extremely important to the individual, his family, and industry. They are intimately associated with group attitudes. The striking contrast between problems relating to technical efficiency in industry on one hand and matters of human cooperation on the other is well recognized in the general curriculum. Furthermore, the formal requirements of the curriculum are adequately supported with opportunities and obligations in the extra-curricular life of the student engineer. This latter feature is also an important factor to be considered in helping a student plan the use of his time in college.

A review of the present placement of the 196 Agricultural Engineering graduates from the University of Nebraska indicates that they have the basic training necessary for entry into almost every field where there are problems of maintenance, production, development, design and distribution. Their assets are a good basic engineering training, fundamental training in non-engineering courses important in their living and working, and a farm background where they have had many opportunities to solve real problems requiring thinking in terms of economic results.

Summary

1. No practical undergraduate curriculum can provide all the training necessary to the graduate in his subsequent life, and it is impossible to predict his future activities accurately. The study plan needs to provide only limited opportunity, if any, for specialization. A real problem in curriculum and course planning is to determine what fundamentals are important.

2. If the graduate is trained in broad fundamentals properly supplemented by practical applications in his general field of interest and instilled with a burning enthusiasm for engineering work in that field, it is quite likely that he will grow thereafter with additional study as the needs of his life unfold.

3. A graduate program based upon advanced technical subject matter should be available so that more specialized study may be pursued with a vigor consistent with such preparation.

4. The student, the teacher, the curriculum, and the employer should be guided in their judgments by the fact that the undergraduate curricula and college life are near the beginning, not the end, of an engineering career.

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Doctoral Study in Industrial Engineering*

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Doctoral study in industrial engineering is relatively new. Prior to World War II, very few schools had organized instructional programs leading to doctorates in industrial engineering and few doctoral degrees in this field were awarded. Some indication of the growth in this field is given by the fact that in 1933–34, no doctorates were awarded in industrial engineering whereas four doctorates were awarded in 1948–49 and three were awarded in 1949–50. There were five doctoral students in industrial engineering in 1933–34 whereas there were fifty-nine in October 1949 and there were forty-three in October 1950.

To obtain data on current practice among a number of schools awarding doctorates in industrial engineering, a questionnaire was sent to the eight schools reporting doctoral students in the ASEE—U. S. Office of Education annual enrollment survey. Replies were received from the following seven schools: Columbia University, Iowa State College, Johns Hopkins University, New York University, Ohio State University, Pennsylvania State College, and Washington University (St. Louis).

The practices and experiences of these schools are generally quite new. Many are still in the process of developing their approaches to the questions discussed in this paper. It is hoped that this discussion of some of the problems and present practices will prove helpful in the further development of effective doctoral study programs in industrial engineering.

*Presented before the Industrial Engineering Division at the 59th Annual Meeting of the ASEE, June 25–29, 1951, in East Lansing, Michigan.

Objectives of Doctoral Study

The aims of doctoral study in industrial engineering may be categorized as follows:

1. The extension of the technical knowledge and competence of the candidate in the fields of industrial engineering to a sufficiently high level that he may be considered to have mastered the principles important to practice in these fields.
2. The equipment of the candidate with substantial tools for scientific analysis and independent rational exploration and performance in industrial engineering fields.
3. The contribution by the candidate to knowledge of a particular phase of industrial engineering. This last aim is usually served by the performance of an original investigation.

When a school has adequately accomplished these aims in its doctoral training, it will award doctoral degrees to candidates who are able to: recognize industrial engineering problems wherever they exist; discern the true nature of the problems; devise an intelligent approach to the solution of the problems; execute the investigations required by this rational conception of the problem solution; design effective and efficient experiments to test the validity and reliability of his solutions; collect and digest his data; correctly analyze and properly evaluate the results of his experiments; record his results and conclusions in a clear manner which is understandable to his fellow industrial workers; and give effect to his conclusions by selling himself and his rec-

ommendations and by following through with training and installation of procedures where required.

The survey disclosed differing emphases on some aspects of these goals by various schools. One department considered its principal goals "the development of men who can think independently; can bring a creative viewpoint to the analysis of problems; can use the English language with correctness and facility in exposition; have sufficient fundamental knowledge of the field and the surrounding fields to be competent in the evaluation and/or direction of research in the field." Another department considered its purposes "to train industrial engineers of full professional competence, with a sound science—humanities background including psychology, sociology, economics, et cetera. The goal of such people should be to improve present inadequacies in industrial engineering practice by research and application." A third stated its objectives more broadly: "to qualify candidate for unusually successful industrial career; to qualify candidate for teaching career; to contribute significantly to fund of knowledge in Industrial Engineering or Industrial Psychology."

Responsibility for Personality Training

It is apparent that, by and large, the various departments feel that their aim is to educate rather than train—to promote the study of fundamental principles which are capable of broad application and which will develop the capacity of the individual to perform successfully in industrial engineering fields rather than the acquisition of skills in the use of specialized techniques. A mature personality with abilities for cooperative action as well as creative independent thinking and scientific curiosity is important in the enlargement of the individual's performance capacity.

However, opinion on the question of responsibility for personality training of doctoral students is quite varied. Two departments replied that they considered that they had a responsibility for personality training and one of them included specific course work. Two others considered that they had a responsibility for bringing any personality deficiencies to the student's attention for his own corrective action. One school was not too sure if it had any responsibilities for personality training and one stated emphatically that it had none. Another asked "can you 'train' personality?"

Screening Procedures

Not all industrial engineering students are likely material for doctoral study. While many of the abilities previously outlined can be acquired through study and training, the candidate must possess a certain minimum of inherent creative powers if he is to successfully complete a high calibre doctoral program.

With small numbers of full-time students, informal methods of restricting enrollment to qualified persons may frequently be adequate. With the larger number of students currently seeking advanced degrees in industrial engineering, many on a part-time basis, formal screening procedures are required to maintain high standards of scholarship in doctoral studies and to save the time and efforts of persons who are not endowed with the necessary qualifications. This screening process is most effective when it exerts its principal effects at the earliest stages of doctoral study.

Admission to Graduate Study

Admission of doctoral students to graduate study is generally limited to properly qualified students on the basis of the satisfactory completion of minimum academic undergraduate requirements. The student's undergraduate record, his standing in his graduating class, and the recommendations of his instructors are all used to varying degrees to ascertain the qualifications of the student.

Five of the seven schools require an undergraduate degree in engineering. Four of these five schools have definite

specified undergraduate course requirements whereas the other three schools appear to have rather flexible requirements. The four schools require that, in addition to meeting all undergraduate prerequisites for graduate courses, the student must complete specified undergraduate industrial engineering courses in such fields as: industrial organization and management, engineering economics, statistics, accounting and cost accounting, production and factory planning, motion and time study, quality control, psychology, physiology, et cetera. No school requires all of these courses and the emphases show wide variations. One school reports an attempt to break away from formal, rigid admission standards, requiring only "a broad general stipulation of science—humanities."

Admission to Candidacy

All schools give examinations for admission to candidacy. The examinations are comprehensive, covering a wide area of industrial engineering and some related fields. They are written by the department staff (plus, in some cases, members from other departments concerned with the doctoral courses of study) and therefore reflect, to some extent, the point of view and interests of these persons.

The subject emphasis on these examinations show some basic uniformity with quite a variety of stress given to fringe fields. As would be expected, all seven schools appear to give an important role to what is normally called industrial organization and management. Six schools mention some aspects of economics: four specify engineering economy, one political economy, and one does not specify the kind of economics. Four departments mention the following subjects: production planning and control, psychology, quality control, and accounting fields. Three mention the general field of methods study (work simplification and motion and time study). Two mention statistics, personnel, safety, and mathematics. Other fields mentioned by individual schools include tool design, industrial experimentation, and industrial forecasting. This tabulation gives a rough picture of the fields covered in the doctoral qualifying examinations. The subject matters of the fields overlap and the amount of emphasis within each school was not considered.

Two schools mention that they give a case problem type of examination. At one of these schools (N. Y. U.), an actual company is chosen and, with some modifications, a descriptive package is prepared on the products, markets, facilities and layouts, personnel, production methods, organization, financial status and history, product design and development, inspection and quality control procedures, sales and marketing policies, et cetera. This package is mailed to the candidate several weeks in advance of the date of the examination. The candidate is then questioned in both the written and oral portions of the examination to determine his technical competence in the various fields of industrial engineering and his ability to integrate and apply his knowledge to this company's problems.

The oral portion of the examination may frequently be more revealing of the candidate's abilities and capacities than the written part because it allows the examiner to determine more thoroughly the limits of the student's understanding of the problems. Thus five of the seven schools reported that their examinations for admission to candidacy have both written and oral portions. One gives a written examination but the examining committee may give an oral examination if it deems one necessary. Another school's examination is entirely oral.

Research and Thesis Requirements

The thesis undertaking serves several purposes: it provides a medium for disciplining the candidate in logical methods of thought as well as for maturing and testing his research ability; it provides training in effective self-expression; and it furnishes a mechanism for promoting

independent investigations for extending the boundaries of knowledge in the field. In general, the doctoral thesis should be related to the individual's interests and occupational plans as closely as possible because it will then have a functional interest and meaning to him which may otherwise be lacking.

Satisfactory definition of what is an acceptable research undertaking is difficult. Some quotations from the schools indicate the trends in industrial engineering departments: "Thoroughly competent study of a definable section of industrial management; the production of a valid contribution to knowledge in that section; production of a publishable thesis or abstract of that thesis"; "(1) Original; (2) Fundamental rather than application; (3) Laboratory investigation preferred to library research; (4) Philosophic development, including hypothesis and experimental trials to prove or disprove"; "I prefer advancements of general methodology and theory supported by experimental evidence."

Course Requirements

Because the doctorate is not awarded on the basis of the accumulation of a given number of graduate credits, variations in the minimum number of credits required for the degree are not of much significance. Many schools regularly require more than the minimum number in their approved doctoral programs and the bases for evaluating and assigning credit points to graduate courses and research and thesis work are quite varied. The basic universal requirement appears to be three years of full-time work after the bachelor's degree, of which approximately one year is supposed to be spent on research and dissertation (which may sometimes be performed concurrently with parts of the two years of course work).

Rigid course requirements for the doctorate reduce programming flexibility. Superior students are required to cover material in which they are already proficient. Candidates with unusual interest combinations are discouraged from following a logical, but out-of-the-ordinary, program. Only three of the seven schools require that all doctoral students take a specified list of graduate courses, varying from four to eight courses. These course requirements correlate quite closely with the subject emphases on the Admission to Candidacy examination. The remaining four schools do not presently have such course requirements. One of these latter schools indicates that it very definitely seeks an absence of the rigidity which such requirements impose.

Five schools have a requirement that courses be taken in one or more minor fields. Two of these five recommend, but do not always require, two minor fields. One of the schools which does not require a minor advises its students to take minors in economics and psychology.

Seminar type of instruction is used extensively by most departments. In one school which has small enrollments, all its instruction approaches the seminar type. Another department uses the seminar type instruction practically all the time after the first post-bachelor year. As might be expected, the schools with the large enrollments do not appear to use seminar type instruction to anywhere near as great an extent as those with smaller enrollments.

Experience and Personality Requirements

One school requires that the doctoral student have "substantial professional experience." This usually means about five years or more, but it allows for weighting according to the nature of the experience. Another has no defined requirements, but will allow experience to be substituted for undergraduate course deficiencies. The other schools have no experience requirements, although one reports that all candidates in the past have had experience.

Three of the seven departments stated that their doctoral students are supposed to have personality characteristics indicative of successful professional performance. These schools indicated that they

considered personality characteristics to the extent that they will affect the candidates' professional careers. One of the four who reported no requirements answered the question of whether it thought a school should have them with the reply: "Yes if valid requirements could be established. How do you do it?"

Language Requirements

All schools have foreign language requirements for the doctorate. Three require one language, three require two languages, and one requires either a comprehensive knowledge of one or a dictionary knowledge of two.

Opinion was divided on whether these language requirements are correct and valid or might be considered a relic of the past. Most departments seemed to incline toward the latter view. "Essentially a hurdle." "Should be eliminated in favor of additional course work or research." Two other schools considered the language requirements a relic to some extent, but one of these thought that it might be worthwhile for training men of broader perspective. Only one school was strongly in favor of the requirement, emphasizing, however, that steps must be taken to make it significant.

Breadth and Integration of Knowledge

Ours is the age of specialists. There was a time when the family doctor worried about and cared for the entire body of his patients from infancy through old age. Nowadays, the baby is delivered by an obstetrician and is cared for in infancy and childhood by a pediatrician. You consult one doctor about your throat, another about your nose, and a third about your ankle. There is much to be said for this procedure: with the increasingly enlarged boundaries of knowledge, it is difficult for a man to become expert in more than one or a few specialties. There is thus a growing tendency for each person to narrow his field and intensively cultivate his own little garden.

This high degree of specialization in our modern industrial society produces a serious coordination problem. Is the treatment of the nose coordinated with the treatment of the throat? In considering problems of the ankle, does the doctor consider its relation to the foot? In other words, does the doctor have perspective?

Everywhere, including our own field of industrial engineering, there is a growing army of specialists who lack perspective. Doctoral study programs are confronted with the problem of counteracting this trend. The candidate should become expert in his chosen area of specialization. However, this should not be accomplished at the expense of a good broad perspective. The doctoral candidate should have breadth of knowledge in all fields of industrial engineering and management and should be able to integrate his knowledge of these specialized fields. He should be able to tie his thorough acquaintance with these specialized fields to the vast expanse of related human knowledge.

ANNUAL MEETING

June 23–27, 1952

Dartmouth College **Hanover, N.H.**

Four Year vs. Five Year Engineering Course

By GEORGE J. BARKER

Chairman, Department of Mining and Metallurgy, University of Wisconsin

I have been asked if I would discuss the four year educational program as compared to the five year course. First, allow me to make it clear that I am not opposed to a five year program but that I am in favor of the four year plan under present unsettled conditions of our national economy. All of us are entitled to our own opinions and beliefs and we should act accordingly when we build an educational program. However, we should be absolutely sure that our opinions are right and our plans are the very best of our thinking before we accept a program to be inflicted upon a young student entering the engineering profession.

I clearly remember many years ago I was a strong advocate of the five year scholastic program. I almost said the "five year plan" but hastened to change the wording in fear of being asked to appear before an investigating committee in Washington. It was at the annual meeting of this Society in 1939 at Pennsylvania State College that the five year curriculum was discussed pro and con. One of the officers of the Society made the public statement in the meeting that, whether we liked it or not, the five year program was to be forced upon us and we would be compelled to accept it. I felt that this was an unfortunate statement because whenever you tell an engineer in the educational field he will be compelled to teach in a manner with which he is not in full agreement, you create an antagonism which can be a very destructive force. Personally, I feel the antagonism generated at that time prevented the five year course from being generally accepted by our engineering colleges.

To me it is not a question of whethe we teach a student for four or five year The important point is what do we teac and how well do we impart knowledg and a desire to learn to the student.

Present Curricula Out of Date

Speaking personally, this is my own opinion and is not meant to cast reflec tions on any one. I am firmly convince our present curricula, whether it be fo four or five years, is completely out o date. When I entered the university th main mode of travel was by horse an buggy. Then came the auto, the airplan and now the jet. We have made vas strides in our mode of living but ask yourself if we have made the same prog ress in building curricula. If you examin the various programs for the freshma engineer you find most of us requir English, Mathematics, Chemistry an Drawing. This is exactly the same pro gram required thirty years ago. And wh have we not changed it and kept abreas of progress? Is it because whenever we ar about to change a program we examin the catalogs of like institutions and say "This is what the others are doing"? Thi course of following blindly in the footsteps of others is not progress. If we are to keep abreast of the world as it is develop ing today we must change our program. By change I do not mean to a five year course but, rather, a change in the present four year course. For instance, why should we not remove English from the freshman year? Such a proposal shocks you because you can hear the howl of pro tests that immediately would arise. How ever, if you will carefully examine the

question you must eventually arrive at the conclusion that there is no good reason for teaching English in the freshman year except that that is where it has always been taught and to change it would be a sacrilege. I can advance many arguments why it should be changed but the important one would be that the manner in which English is taught today to our freshman students is a practical waste of the student's time—time which is so valuable and should be used to better advantage in the student's curriculum.

Teaching Assignments

While I am on this subject of suggesting ways of making a better engineering course, could I give you one more example of what is wrong in our education work? Most of you are familiar with the cost of education and you know that it is common practice to employ many graduate students for part time instruction to keep down the cost. Most of these instructors are assigned to freshman instruction. I am fully aware of the advantage of having the pioneering spirit of youth and the experience of age on the teaching staff, but I am firmly convinced we are making a serious and costly mistake in our classroom teaching assignments. I would favor the assignment of the experienced teacher to the lower level classes and to graduate teaching, with the younger instructors handling part of the upper classes. All of you have deplored the heavy casualty list of students in the first year in the universities. We pass it off by saying the student "just has not got it" and should be eliminated from further education. I say this is morally wrong. We should give the young student the very best of inspired instruction and salvage this staggering loss of humanity which is a disgrace to our educational system. There is an additional advantage to the proposed system of using younger instructors to teach upper classmen. They would know it would be necessary to better prepare their class instruction and this would materially improve their own knowledge of the subject matter.

I am sure many of you have been placed under some pressure recently by some of the propaganda which has been fed us, namely, technological development, which has been so rapid recently that society has not been able to keep pace and adjust itself and that engineering should slow down until the social sciences can catch up. Also, the engineer should include more humanistic and social studies in his program. This, as has been pointed out, could be done by lengthening the student's time to five years in college. In general, I am opposed to this plan. As an engineer you look at facts and base your decision upon these facts. So, let us examine the facts. By far and large, the greater number of students in colleges today are taking the humanities and social courses.

For the past generation graduates of these courses have taken their place in society and, because of college training, have assumed places of responsibility. Presumably, many of them have entered public service and it is only necessary to take a quick glance at the situation in Washington today to make us realize what a failure our general educational system has been. Today the plea is for the engineering students to take more humanistic and social studies so they may be better fitted to enter into the affairs of our national government. To me such a plea is not worthy of consideration by any clear thinging engineer. Our engineering graduates of today are far better trained for public service than any other group of students. And why? Because we, by engineering training, have taught the student to analyze the facts and then proceed on these facts in an *honest* manner. The one word, honesty, is the key to the whole situation. We teach honesty to ourselves and then honesty to others follows automatically. I repeat, the engineer is now receiving this training and because of it, he better understands the rights of others,

and has a clear concept of the problems of humanity.

And, so, I do not favor at this time addition of so-called social and humanistic studies to an engineering curriculum, but I do advocate the inclusion of engineering courses into the liberal arts curriculum so those students may at least have some contact with clear and logical thinking. By this same reasoning, I cannot agree that the five year course has some advantage over the four year course, simply because it allows more time for the student to receive a more so-called liberal education.

Strengthen Course Content

Coming back to the main question of the four year curriculum, this should not be lengthened but the course content should be strengthened. With the present acute demand for graduates we should supply the need as rapidly as it is possible to send out adequately trained men. With the high cost of living and the loss of present high wages paid to graduating engineers, you can estimate it will cost a boy, roughly, five thousand dollars to spend an extra year in college. This is an economic waste, provided we do a good job in teaching the student during the four years he is with us. Our engineering graduates enter so many various fields of endeavor, it would be impossible and very foolish to try to give complete and adequate instruction in every field which offers employment. Therefore, it is essential that our four years' training be concentrated on a thorough mastery of the fundamentals of the various fields. We must not build a curriculum on credit hours but upon course content. If the graduating student has received sound training in the fundamentals, his prospective employer knows he can give the graduate the necessary training to fit him for the position for which he was hired. In general, large industries which are hiring our graduates are not asking for more special training but actually will accept less if the student has been well trained in the fundamentals.

I am very willing to acknowledge some few students can and will benefit by longer training. If the particular individual desires to specialize in a particular field, to do advanced work or train for research, then he should enter the graduate school for this additional training. Most universities have strong graduate courses and the additional training is available if desired by the few.

In my early engineering training I readily learned the value of the courage of my convictions. Today I have the courage and, because of it, will be convicted by some of you. It has been a pleasure to inflict upon you some of my thoughts and ideas. I know many of you will not agree with me but I sincerely hope I have set forth ideas to which you will give careful consideration and by this consideration improve the quality of our engineering graduates.

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Electrical Engineering Summer School

The Electrical Engineering Division will hold a Summer School at Dartmouth College on June 20 and 21, 1952. The theme will be "Undergraduate Teaching of Electrical Circuits and Fields." Registration will be $1.50. For further details address Dr. J. C. Ryder, Electrical Engineering Department, University of Illinois, Urbana, Illinois.

The Electronics and Communications Options—Why?

By J. D. RYDER

Professor and Head of the Electrical Engineering Department, University of Illinois

It does not seem possible to discuss curriculum options in electrical engineering education until we know what we are trying to accomplish, or what are the objectives of electrical engineering education. We are given certain raw material from the high schools. What sort of product do we wish to make of that material four or five years hence? If we have an answer to the type of product desired we are then in a much better position to determine what processes should be applied to the material during the period of manufacture. Industry, as our customer, frequently tells us what qualities they desire in that product, but they are in no position to indicate the manufacturing processes we are to use.

At the moment it appears that industry would like a graduate having two somewhat contradictory abilities; namely, a technical level of achievement considerably higher than that expected 30 years ago, and the ability to live and work with other people. The objective of our academic efforts should be directed toward satisfying that demand.

It has occasionally been said that an engineering education should be sufficient to enable a graduate to hold a job for a few years until he could learn to be an engineer. If this is the objective of our teaching efforts we should so inform our students, since we are obviously not planning to deliver that which they expect. Such an objective appears to place some sort of a top limit on our teaching efforts since we seem to have stated that we are unable to prepare a man for anything more than a job immediately upon graduation. The training of a man to hold a specific job is the objective of a trade school and not one which should be fitting to an institution of higher learning.

Even if this statement were our actual objective it is not a desirable one since it seems to say that our objectives are limited, that our efforts can only accomplish so much, therefore why attempt to accomplish more? It seems more desirable to have as an objective some statement which furnishes a goal, not a limit, to our efforts.

There are, of course, those who will argue that we cannot turn out engineers but can only teach engineering, and to some extent this is true; however, it can also be argued that we should attempt to teach our engineering in such a way as to make the best possible engineers fifteen or twenty years after graduation, and it does not seem that the above objective supplies the proper incentive for that kind of teaching.

Objectives

It seems desirable to propose as an objective of electrical engineering education:

> Upon completion of their college work, our graduates should be prepared to continue learning, to grow with the field, and to go with that field as it moves into new areas of learning.

Our objectives are then stated so as to lead us on as a path into the distance rather than in a form which serves as a

closed gate. Our graduates should be prepared to meet and solve new problems as they arise, which means that they should have understanding rather than superficial knowledge, and should be taught the fundamentals to many problems rather than solutions to a few. We should prepare our graduates to meet and understand new systems and new devices as they arise, and should not allow to be again repeated the troubles of a 60 cycle power man upon the advent of radio and electronics.

Much of the above seems to be an argument for the teaching of fundamentals. It is then proper to ask—if only fundamentals are taught why are curriculum options necessary since the fundamentals are the same for all?

It seems that such a question carries at least an implied premise, and may imply agreement with a fallacy. That is, are the fundamentals in *usable form* really the same for all types of electrical engineering problems?

We might argue that an understanding of the reactances of the synchronous motor is fundamental to the study of that machine for a power student. We could likewise argue that understanding of the orientation of the magnetic field in a TM_{10} excited wave guide is fundamental to the understanding of electromagnetic propagation in guides for a communication student. Thus the fundamentals are not the same for all since we can hardly argue that a vice versa relationship of understanding by our two hypothetical students is essential to success in their respective fields.

If one wishes to argue that these two examples are not fundamental but are merely applications, it is possible to reason back step by step until one comes to the realization that the common ground for our two students and therefore the common fundamentals of the problem lie in the understanding of the transmission of energy through electric and magnetic fields.

If only the fundamentals are to be taught in this area of knowledge, we will teach our students that the energy in a magnetic field is expressed by $\mu H^2/2$ and the energy in an electric field is given by $\epsilon E^2/2$. We cannot teach the students that the rate of flow of this energy through the electromagnetic field is given by $E \times H$ or Poynting's vector since someone will point out that is an expression used predominantly in the communications area and is therefore not a fundamental for all students. We might also attempt to teach machines to our students by considering the magnetic field only, which is the usual teaching method for machines, but our radio friends will immediately point out that there must be an accompanying electric field wherever there are time-or space-varying magnetic fields, and therefore such a consideration of the magnetic field alone is not fundamental.

This dilemma might be resolved by a proposal to teach the true fundamentals, Maxwell's equations, in which the actions of fields in synchronous machines or in the wave guide are mathematically described. We can, of course, immediately expect the power-interested faculty to argue that those equations have little use in the machine area. In return it might be stated without further proof that these equations are little *used* there, but actually could be of considerable help in certain anomalous situations.

Fundamental Knowledge vs. Fundamental Methods and Techniques

It seems proper to suggest that we are confused between the teaching of *fundamental knowledge* and the teaching of fundamental *methods and techniques* to use that knowledge. Our fundamental knowledge may be considered as wrapped up in Maxwell's equations, Newton's laws, and the conservation of energy and momentum, subjects which can be readily taught. However, as illustrated by our example of the students being taught magnetic fields in machines and wave guides, teaching of only these common fundamentals leaves our student ignorant of the higher level methods and techniques which

can make that fundamental knowledge useful.

These methods on which we spend so much time may include complex algebra, vector diagrams, graphical solutions, flux plotting, harmonic analysis, symmetrical components, the vacuum-tube equivalent circuit, the Laplace transform, and many more. It is these methods on which we concentrate and an electrical graduate would be in a rather poor position if we denied him these techniques.

If we are willing to consider the teaching of these methods and techniques as necessary then we are faced with the necessity of curriculum options. Certainly some of the methods given above are suited to specific fields, and can be best taught when illustrated by applications in those fields.

In a field as broad as ours, it is necessary to have some division in order that the fundamental material may be suitably chosen and presented with a suitable viewpoint. In each area the fundamental knowledge must be restated, reoriented, and presented with the suitable viewpoint to be of use in connection with the fundamental methods and techniques of the area.

If we accept the definition that our "fundamentals" are composed of both knowledge and methods, then we seem led to the practical necessity for curriculum options. There seem to be at least four arguments to support the division of the field into at least the power and communications or electronics options.

Arguments in Favor of Options

The first argument in favor of options is simply that we have always had an option in electrical engineering. Webster defines an option as "that which is offered for choice" and up until possibly fifteen years ago we offered the student an option in machinery and he was at liberty to take it or leave it. If he left it he could still become a mechanical engineer or physicist, and a few schools were quite blunt in telling their students so.

A second argument is illustrated by the "reductio ad absurdum" method employed in the little problem concerning synchronous reactance and the magnetic field in the wave guide, wherein it was necessary to go so far back into fundamentals that very little was left. In other words, to bring a man up to a suitably high technical level in any field requires specialization and the learning of special *methods* inherent to that field, although not necessarily the learning of special fundamental knowledge. The general technical level in electrical engineering has advanced very greatly in the last twenty years, and we find it necessary to carry our students up to that higher level if they are to be able to continue to grow in the field after graduation.

It is also possible to teach the use and understanding of fundamentals through applications of those same fundamentals. A good student given Maxwell's equations can find it possible to solve a great many field problems sent his way. A poor student must be shown how to apply these equations. To many people Maxwell's equations mean very little in themselves. After being shown how to use them they become very valuable tools and in their use we learn to further understand and appreciate the original equations. Thus the teaching of the fundamentals becomes improved through the choice of proper applications.

A fourth reason for options may at first hand appear trivial, but to anyone who has taught service courses, or who has taught machinery to electronics men, it is very definitely not trivial. This is a matter of student motivation—the driving force which makes a student want to learn and to understand the material being presented in the course. Good teachers can frequently supply this in even the most uninteresting courses, but a poor teacher cannot, and thus anything we can do to aid will be an improvement in the student learning process. An electronics student is interested in matters associated with electronics. He is not interested in the details of the design of a synchronous machine. He will study harder on an

electronics problem whereas his machinery books will be pushed aside. A power student is interested in machinery or in power transmission, and understanding of the mathematics of modulation means little to him.

There is a danger present in the use of options if carried .to such a point of specialization as to seriously limit the area of training of the student. We cannot know in what field a graduate may work five, ten, or twenty years after graduation, and rarely does the student have any firm expectations in this direction. In fact it can be said that ten years after graduation the type of product manufactured by his company will be of little importance to him, and that the really important factors at that time will be the general business policies of the company with which he is associated, and the opportunities to grow and advance which are inherent in his position.

Thus a desirable statement of policy on options seems to be—A minimum number of options is desirable, but the material chosen for any option should only be so narrow as to keep the student happy, and broad enough that there should be no damage to his education.

In Memoriam

Charles Ellison MacQuigg

Charles Ellison MacQuigg, past President of the ASEE and Dean of the College of Engineering at Ohio State University, died on April 24, 1952, in University Hospital, Columbus, Ohio.

Dean MacQuigg was born in Ironton, Ohio, on January 19, 1885. He graduated from Ohio State University in 1909 with a degree in Mining Engineering. He was awarded the Doctor of Engineering Degree by Clarkson College of Technology in 1946. He served as an engineer for the Sante Fe Railway Company and the Anaconda Copper Mining Company, 1909–1912. He was head of the Metallurgy Department of Pennsylvania State College, 1912–1917. From 1917 to 1919 he was Captain, Ordnance Department, U. S. Army. During World War II he was a Lieut. Col. in Ordnance Reserve. He was affiliated with the Union Carbide and Carbon Research Laboratories, Niagara Falls and Long Island City, New York, 1919–1937.

He became Dean of the College of Engineering at Ohio State University on July 1, 1937 and Director of the Ohio State University's Engineering Experiment Station. He was president of the American Society for Engineering Education, 1947–1948, and a member of the executive committee of the Engineering Division of the Association of Land Grant Colleges and Universities. He also had been a member of the National Research Council, and was currently a member of the Newcomen Society of England, Sigma Xi, Tau Beta Pi, AIMME, ASM and AAAS. He was a Fellow of the Ohio Academy of Science and a recipient of the James Turner Morehead Medal of the International Acetylene Association. He was a trustee of the Orton Foundation and a member of the board of directors and executive committee of the Ohio State University Research Foundation.

President Howard L. Bevis of the Ohio State University described Dean MacQuigg as follows:

"No man was more loved by students, no man more respected by the entire faculty. He was tireless in service. He gave himself without reserve to every cause in which he could be of practical help. He was a Christian gentleman who served science with distinction."

Dean MacQuigg is survived by his wife and three sons: Dr. Rodger E. MacQuigg, M.D., a surgeon, of Albuquerque, New Mexico; Major David E. MacQuigg, M.D. of the U. S. Army at Ft. Riley, Kans.; and Charles H. MacQuigg of Dallas, Texas.

A Philosophy of the Science of Graphics

By JOHN T. RULE

Professor and Head, Section of Graphics, Massachusetts Institute of Technology

This paper was written to be delivered to teachers of engineering drawing and descriptive geometry. Its entire intent was to stimulate interest in, and enthusiasm for, the comparatively undeveloped field of pure mathematical graphics. To the rigorous mathematician it will appear loosely written and will certainly raise a host of unanswered questions. I make no apologies for this for I believe the core notion of a science of graphics is a valid, though vaguely realized one. The prime business of the moment is the recognition of the problem.

It is my firm conviction that the science of graphics is an unrecognized science which offers the creative mind a tremendous challenge in a relatively unexplored world. This is the theme I wish to develop by offering a tentative, usable definition and in its light sketching a few of the possibilities.

Undoubtedly mathematics started with counting. As a matter of fact, to most human beings that is all that mathematics ever is, for the normal layman never needs anything but arithmetic, which is the science of counting. It involves a number system divided into units—one, two, three, etc. It thus has inherent in its structure the process of proceeding by steps. By developing fractions and decimals the steps are made as small as desired but remain steps, nevertheless. Thus 3.1416 represents pi to the nearest step when the steps are 1/10,000 of a unit. 3.14159 represents pi to the nearest step when the steps are 1/100,000 of a unit. Arithmetic is thus discontinuous in nature.

At some point in history geometry began to develop as the mathematics of space relations. Originally it was probably a practical business. It was lifted into the realm of consistent theory by Euclid and his school. Now, curiously enough, Euclid founded the science of graphics on the one hand and did it a profound disservice on the other. Perhaps he recognized the discontinuous, step-nature of arithmetic as opposed to the continuous nature of geometry and wished not to contaminate the latter when he restricted all constructional geometry to the use of the unmarked straightedge and compass. Whatever his reasons, he achieved two things. First, he barred the use of other curves than the circle since such curves were obtained by finding a limited number of points and fairing between these, which was not theoretically acceptable. Thus we still say we cannot trisect an angle. Second, in barring the marked ruler he barred the graphical device for converting lengths into the number system. He thus fixed the space nature of geometry by eliminating its calculational possibilities and in addition put a psychological barrier in the way of converting it into pure symbolism, which is the soul of the science of graphics.

That Euclid's straight-edge and compass restriction is an artificial one became apparent when the Italian mathematician Mascheroni showed that all the constructions possible with a ruler and compass alone may be made with the compass alone (provided that a straight line is thought of as given by two points. We cannot draw the line but we can find where it would intersect

another line or a circle, if it were drawn). Later Jacob Steiner showed that all these constructions are possible with a straightedge alone provided that a single fixed circle and its center are given.

Nature is Unruly

Thus we had until Newton's time a counting mathematics and a space mathematics. Unfortunately nature is a very unruly damsel. She knows nothing of counting which is a pure product of the human mind. Furthermore, she has a passion for the continuous as she, herself, is in a state of continuous change. Time and distance are continuous. Mass is effectively continuous above the atomic level. Thus a pure counting mathematics no longer sufficed as soon as we really seriously attempted to describe nature mathematically. Leibnitz and Newton enmeshed the continuous in mathematical symbolism by developing the calculus. The theory of limits bridged the gap. From our point of view it is noteworthy that this was done by converting the symbolism of counting mathematics into functional mathematics.

Thus, today, we have an extremely powerful equational, functional mathematics for dealing with physical reality. In many instances, however, it is very cumbersome. Furthermore it almost never exactly fits the facts. I want to emphasize this point. Equations are abstracted laws involving an artificially limited number of variables. However the physical universe refuses to conform to simple classical rules. A falling body falls according to the well-known formula only when we make very artificial assumptions, neglecting air resistance, variations in air density, etc. Thus we capture fundamental portions of nature in our equational world only by greatly oversimplifying the natural phenomena involved.

We cannot always do this. For instance, the resistance of a boat hull in moving through water, or of an airplane fuselage in moving through air depends on so complicated a set of factors that we measure these forces in model towing tanks or wind tunnels and make little claim to being able to predict them mathematically.

The basic trouble here is that we are substantially lacking one whole branch of mathematics, a branch that can describe completely by symbolic means physical phenomena far more complex than equational mathematics can. This branch of mathematics is the science of graphics, the nature of which has never been fully understood because of the wet blanket of Euclidean notions and the great success of equational mathematics and, in addition, because of its lack of oral quality.

The latter is a crucial factor. When I write 6 and say "6" I have a one-to-one correspondence between the written symbol and the spoken symbol. When I draw a line ———— I cannot talk about the magnitude it symbolizes until I convert it into the number system.

In order to define the science of graphics we must look more closely at symbols. Take the concept of time. Equationally we say, let "t" represent time. t can have any numerical value we choose. Graphically we say let this straight line represent time, and the line can have any length we choose. In each instance we are tied to a unit of some sort. A time of 100 or a time of the length of this line ———— has no meaning until we say in the first instance one shall be an hour and in the second instance this length —— shall be an hour.

Note that in both instances we are employing pure symbols, one as legitimate as the other. In the second instance, note that we have completely broken with Euclidean geometry for we are using lines as pure symbols for something else and are not tying them to space geometry.

Rectangular Coordinate System

It is important here to note that Descartes tied the space world of geometry to the world of numbers by

means of a rectangular coordinate system. It was basically a space describing system and did not contain the notion of lines as symbols until someone took the next step by assigning time, or the like, to one axis instead of distance. Cartesian coordinates like Euclidean constructive restrictions have been a bar to our understanding of the true nature of graphics. We shall come back to this later when discussing coordinate systems.

With the use of the line as a symbol of something else we establish the science of graphics. We may now define graphics tentatively, for our purpose here, as the use of geometric entities as mathematical symbols for manipulative and predictive purposes. The science of graphics is the science of performing by means of geometric symbols the same operations that can be performed by numerical, algebraic symbols.

The science of graphics is a full-fledged science of the continuous. In certain ways it has some remarkable advantages over equational mathematics. First, lines are continuous and numbers are not. Nature, herself, is fundamentally graphical. The first thing we do in collecting data is to use some form of conversion device for converting the continuous, graphical character of nature into the discontinuous number system. The three great conversion devices are the clock for converting time, the balance for converting mass, and the measuring stick for converting distance. Such conversions mean that in every physical problem except those involving pure counting there is no such thing as absolute accuracy, for the continuous character of nature can be read only to the nearest step in the number system.

Second, and of profound importance, we can symbolize graphically much more complex phenomena than we can symbolize equationally and we can handle successfully many more variables.

In many respects equational mathematics has great advantages over graphics. Thus in the last analysis some things can be done better graphically, some equationally, and a great many by a combination of the two. We cannot, however, fully capitalize on the possibilities until we fully develop the science of graphics.

The task before us then is to establish a set of graphical manipulations which are the analogs, or the equivalents of, numerical, algebraic, and analytic manipulations. Our first job is to develop a consistent, unified theory which will enable us to perform any mathematical process graphically, to demonstrate that the possibility exists that anything that can be done with equational mathematics can be done graphically and that in a very real sense the two are partners in the mathematical world. At the moment we can only begin this. Its full development is the great challenge. I am going to pick one or two arbitrary examples.

Graphical addition and subtraction are obvoius. So, as our first example we will examine multiplication. Suppose we want to multiply this length a by this length b in these units 1.

We'll call them a, b, and 1 (note the necessity of using letter symbols for oral purposes). If I draw two similar triangles, Fig. 1(A), it follows that $a/1 = x/b$ or $x = ab$. Superimposing these, I can lay out a and b at right angles for convenience, Fig. 1(B). I then mark 1 on the b axis, draw from a to 1 and draw a parallel from b to obtain x, the product of a and b, on the a axis.

Examples

Now we can take an example. We wish to multiply the a and b curves of Fig. 1(C) together. We draw a number of ordinates and mark the "a's" and "b's" and lay them out from "0" on the proper axis, paying attention to direction (sign). Next we draw the family of lines from the "a" points to 1 and draw parallels from the proper "b" points to obtain our required products. The process is shown for a_2 and b_2 and for a_8 and

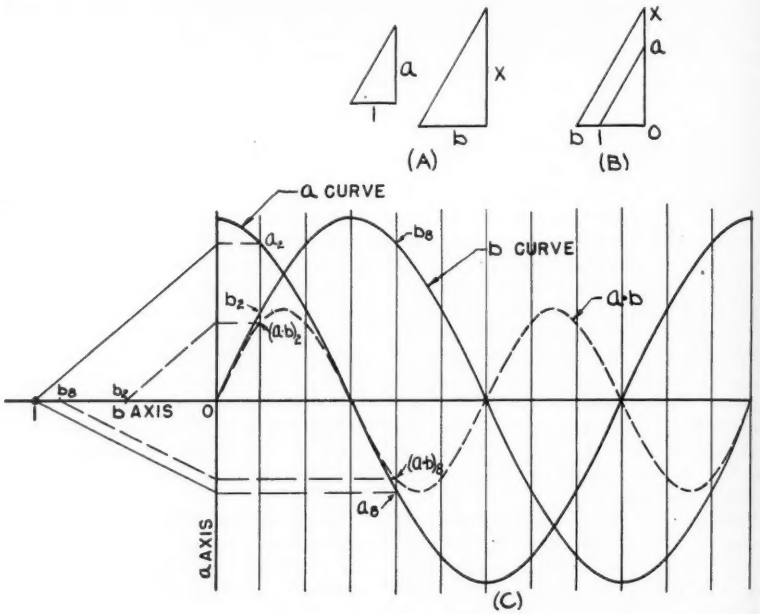

FIG. 1.

b_8 in the figure. We then distribute our products to the proper ordinates and draw a curve through the points. We have now multiplied our two original curves together. Now if we wish to convert this into equational mathematics the two curves are sin θ and cos θ. You will note that the product curve has half the height and twice the frequency and thus is $\frac{\sin 2\theta}{2}$. Thus sin θ cos θ $= \frac{\sin 2\theta}{2}$.

Some comments on the above example are necessary. First we have divorced ourselves from the notion of area—the Euclidean meaning of multiplication. Second, I have used a cartesian coordinate system only in order to make a recognized conversion between the equational and the graphical systems. Third, the inevitable question arises concerning accuracy, in that the two original curves will not exactly fit the theoretically perfect curves for sin θ and cos θ. It is not contended that they do. The two given curves multiplied together yield the third curve. If they are not the curves for sin θ and cos θ then the equational mathematician cannot multiply them together at all for he cannot fit equations to them. Yet they can be multiplied graphically *whatever they are*. It is equational methods that are in difficulty, not graphical. Fourth, this does not constitute a proof that 2 sin θ cos θ = sin 2θ. It does show the pattern of correlation between the two systems.

In similar manner we can perform division. If we interchange the positions of "1" and "a" and proceed as before then x becomes $\frac{b}{a}$. If you care to perform this by dividing sin θ by cos θ you will find the result is tan θ.

Simultaneous Linear Equations

Now let's step up the line a little and consider the matter of simultaneous linear equations. All of you can solve two equations in two unknowns by plotting in cartesian coordinates. All of you can solve three equations in three unknowns by considering each equation a plane and finding the point of intersection of the three planes by descriptive geometry. In both instances you have employed cartesian coordinates and used a space analog of the equations—2 lines in a plane intersect in a point, 3 planes intersect in a point in space. Let's free ourselves from this basic Euclidean concept and look at a method which will solve n equations with n unknowns. (This method is adapted from "Graphical Methods" by Carl Runge, Columbia University Press, 1912.)

We'll take two simple equations for illustrative purposes:

$$3x + 5y + 4 = 0,$$
$$2x + y + 5 = 0.$$

We draw a line (Fig. 2) and lay out on it each of the three coefficients as a length from 0 (the coefficient of x will be called a, of y, b, and the constant c). We draw a second line parallel to the first and do the same for the second equation. I've reversed the direction, but that is of no importance. These marked lines are the graphical equations. We then draw the lines connecting the 0's, the a's, b's and c's. Now, any line parallel to our original line will cut the lines for a, b, and c in points which establish a graphical equation which will be satisfied by the same roots as the two original equations. Consequently we draw two lines, one through the point where the a line crosses the 0 line and one through the point where the b line crosses the 0 line. I thus obtain one graphical equation without a and one without b. Converting these from the graphical I obtain the two equations:

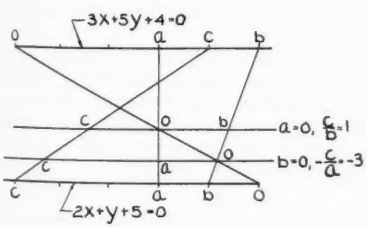

Fig. 2.

$$by - c = 0 \quad \text{or} \quad y = \frac{c}{b},$$

$$ax + c = 0 \quad \text{or} \quad x = -\frac{c}{a}.$$

Since these are scalable ratios I convert into the number system and find that $y = 1$ and $x = -3$ which are the required roots.

We can extend this process to three simultaneous linear equations having coefficients a, b, c, and d by eliminating a from any two pairs and obtaining two new equations in b, c, and d. We then operate on these two as above to obtain our roots. This process can be increased to include n equations in n unknowns.

The solutions of such simultaneous equations might be needed for our old friend the Wheatstone Bridge. The question being what equivalent single resistance may be substituted for the network so that the current passing through will be fooled and not know the difference.

Electrical Networks

We can extend this into a tougher problem in electrical networks. Instead of simple resistances in each branch of the bridge circuit, suppose that there is a combination of inductance and capacitance and resistance. For a given applied alternating voltage of a certain amplitude and frequency what is the resulting alternating current amplitude and phase? Now, an impedance is a complex number so that our simultaneous equations now have complex coefficients which we must graph as vectors in the complex plane. However, the elimination proceeds in a graphical way analo-

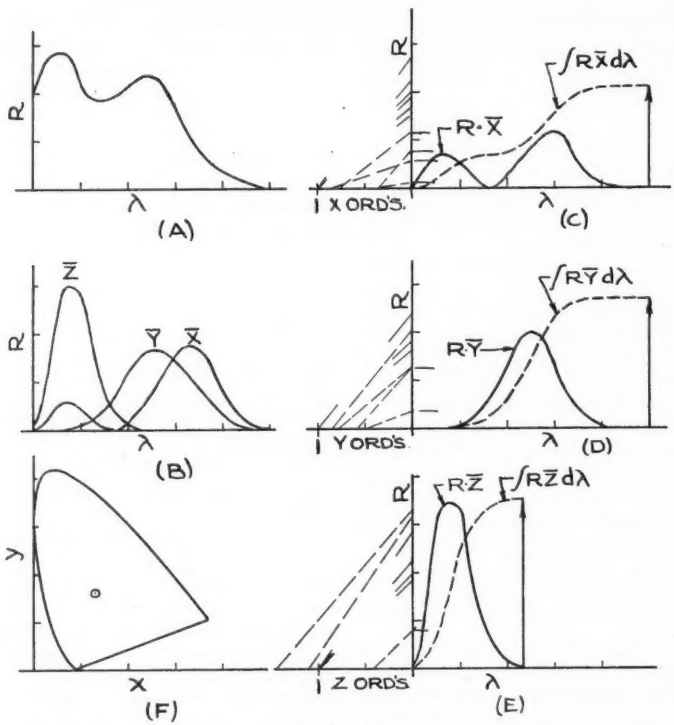

FIG. 3.

gous to the above and the solution of the equations may be found. I won't do it here. I bring in this application to suggest the intriguing possibilities of a comprehensive graphical theory for networks.

There is a similar sort of process for obtaining the roots of higher power equations which I won't go into here.

Next in line are graphical integration and differentiation. You all know that we can do this with a great deal of accuracy and rapidity.

Now, I want to take a physical example of the use of a combination of these processes. In many fields of modern science the simple parabolas and hyperbolas and linear differential equations that used to describe reality are being replaced by empirical curves and functions that more nearly describe the behavior of our universe. I am choosing as an example the tristimulus color problem for it involves curves to which equations cannot be fitted so that a laborious numerical process is usually followed.

Fig. 3(A) shows an assumed curve of reflectance of a dye pigment under a given light source.

It also shows the $\bar{X}$, $\bar{Y}$, $\bar{Z}$ curves, Fig. 3(B), the response curves of the eye to three standard primary colors. Now the blue seen by the eye x will be

$$\int_0^\infty R\bar{X}d\lambda.$$

This is, of course, an impossible equational operation as we cannot find any

equation to integrate. Our first job is to multiply R by $\bar{X}$, Fig. 3(C). We have already seen how to multiply two curves together. This yields the product $\bar{X}R$. We now integrate this from 0 to ∞ and get the x vector. We repeat this process for $\bar{Y}$ and $\bar{Z}$ and get the y and z vectors, Fig. 3(D and E)—a multiplication and an integration in each instance performed very rapidly. Since the sum of the three is unity we can mark the color on the standard tristimulus chart Fig. 3(F).

I want you to note that in solving this very complex problem we have never once left the graphical world. We've operated completely in geometric symbols without ever employing a number. Furthermore, we have followed the complex pattern of physical reality without employing oversimplifications for the sake of getting equations which we can manipulate.

Coordinate Systems

At this point I think you can see the beginnings of a unified attack on graphical procedures. I want to talk a minute or two on coordinate systems for our persistence in using cartesian coordinates highlights the difficulty of breaking our thinking about graphics away from space concepts. If we are going to be successful in this area we must think of lines as pure symbols and operate on them with freedom. We can use any arbitrary coordinate system we choose so long as it is fruitful. We can use line coordinates or point coordinates or any distorted field of coordinates. A coordinate system is basically a conversion device between the two mathematical systems. Since a combination of the two systems is most fruitful in many problems, the free use of coordinate systems without respect to a space analog becomes a very important factor.

You will find that all mathematicians say that $x^2 + y^2 = R^2$ is the equation of a circle. This simply is not true in any broad sense. It is true *if* cartesian coordinates are used but we can show a coordinate system in which it is an ellipse or some other conic.

An interesting problem is that of taking a family of curved lines and developing a coordinate system in which a maximum number of the family are rectified. We can show that this can always be done for 3 such lines, and I suspect a solution exists for 4, but we've been unable to find it.

Another interesting procedure is to project cartesian coordinates by central projection into a system containing two vanishing points. Note that we then can plot any curve out to infinity which has some useful possibilities. I am convinced that we have only begun to examine the coordinate system problem.

Conclusion

In closing I want to point out that we are dealing with a pure science and that our focus of attention should be on pure research without hampering ourselves with the notion of applicability. We have only barely scratched the surface of this science. The mathematician does research for the sake of discovery alone. Applications generally follow discovery. We should treat the science of graphics in the same way and never tolerate the question, "what good is it?". No science of any dignity ever tied itself to the utilitarian.

It seems to me that the coordinated type of attack that I've tried to outline contains the true future of the science of graphics.

I want to acknowledge my indebtedness to two of my colleagues—to Mr. John F. Twigg for the example on graphical multiplication and to Mr. Steven A. Coons as a major contributor of the philosophic ideas and the work on coordinate systems.

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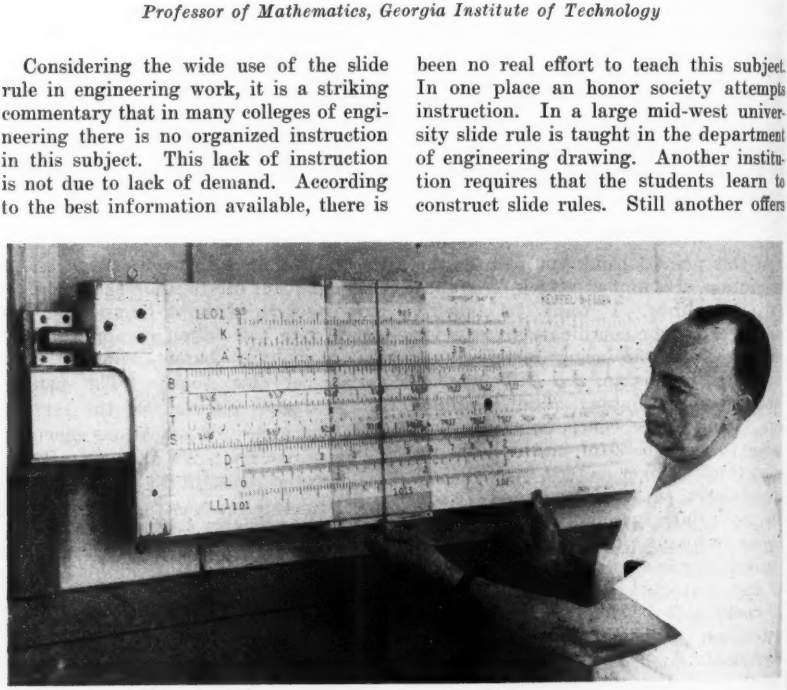
Slide Rule Instruction in Technical Schools

By HERMAN K. FULMER

Professor of Mathematics, Georgia Institute of Technology

Considering the wide use of the slide rule in engineering work, it is a striking commentary that in many colleges of engineering there is no organized instruction in this subject. This lack of instruction is not due to lack of demand. According to the best information available, there is a steady demand for slide rule instruction among undergraduates generally. This demand is further attested by the continued publication of books, instruction sheets, and pamphlets on the various applications of the slide rule. But taking engineering colleges as a group, there has been no real effort to teach this subject. In one place an honor society attempts instruction. In a large mid-west university slide rule is taught in the department of engineering drawing. Another institution requires that the students learn to construct slide rules. Still another offers free group instruction on demand. One of the most serious objections to haphazard instruction is that frequently the best methods are never learned and that, due to the tendency to stick to what is first learned, the student goes through life doing unnecessary work.



SLIDE RULE INSTRUCTION IN TECHNICAL SCHOOLS

In order to meet the demand mentioned above, two years ago the Department of Mathematics of the Georgia Institute of Technology incorporated use of the log log duplex decitrig slide rule as an integral part of the course in trigonometry. By this plan, really borrowed from North Carolina State College, slide rule is not taught as a topic. Rather, it is taught in connection with other topics where the correlation is easy and natural. This method has the very great practical advantage of not trying to cram on all the various applications at once. Early in the quarter, students in trigonometry are invited to a movie (cooperation of Keuffel & Esser) showing basic slide rule operations. Experience shows that this movie aids considerably. Following this, and early in the course, applied problems involving multiplication and division are taught. Along with instruction on use of the tables of natural functions, their use with slide rule is explained. Many right triangles are solved by slide rule. Still later in the course where fractional powers are taught by the use of logarithms, the use of the slide rule for this work is also explained. The rule is also used in the solution of exponential equations like $2^x = 7$. Finally, in the solution of oblique triangles we stress the slide rule.

It is interesting to note that instruction in slide rule seems not to shorten the time allotted to other topics. Rather the speed and simplicity with which many problems may be solved more than compensate for the time spent in learning. The department owns 6 master demonstration rules which are mounted (see photograph) as standard equipment in class rooms. We are indebted to the School of Mechanical Engineering for this simple and permanent solution of the old problem of how to change sides with these large rules. This mounting is not patented and could be used any where. The rules are mounted along the side wall of the classroom, are always available, never in the way.

A recent survey shows that the students appreciate this instruction. We would welcome correspondence and suggestions toward improvement.

Sanitary Engineering Conference

A two-day conference on Sanitary Engineering Education sponsored by Committee 3 of the ASEE Civil Engineering Division, with the cooperation of the U. S. Public Health Service and the American Public Health Association, will be held at Dartmouth starting Saturday, June 21. The program of the conference is as follows:

Saturday, June 21

1:00 p.m.	Radiological Training
1:45	Field Training
3:15	Training Sanitary Engineers (panel discussion)

Sunday, June 22

9:30 a.m.	What is the Present Day Field of Sanitary Engineering?
10:30	Minimum Requirements for Sanitary Engineers
1:30 p.m.	Sanitary Engineering in the Smaller College
2:30	Graduate Program
4:00	Adjournment

Monday, June 23 Committee Reports

Arrangements for the conference are in charge of the following special committee:

Gilbert Dunstan, Chairman	Earnest Boyce
Jess C. Dietz, Co-chairman	E. S. Brown
Arthur P. Miller	William T. Ingram
Ellis S. Tisdale	E. J. Kilcawley

This committee is working in cooperation with Committee 3. Reservations for the conference should be made with Professor E. S. Brown of the Thayer School of Engineering, Dartmouth College, Hanover, New Hampshire.

TIMELY TIPS

A Direct Development of the Polytropic Process

By E. J. WELLMAN

Instructor of Mechanical Engineering, Purdue University

In the presentation of reversible, non-flow processes for ideal gases in most thermodynamics texts, the position of the polytropic has appeared to the author to be incongruous. The constant pressure, constant volume, isothermal, and isentropic processes are naturally grouped because they are characterized by the constancy of a particular property. The polytropic equation $pv^n = C$ (a constant) appears to be simply a convenient mathematical formulation which has little physical significance, but which can be adjusted to fit each of the others by proper selection of the value of the exponent n.

A method of relating all of the above processes involves an entirely different approach which requires a fresh start.

Let us consider, for a non-flow, reversible process, the ratio of heat to work, dQ/dW. Let $dQ/dW = E$. Now if we restrict our analysis to those processes for which E is a constant, we may derive a $p - v$ relationship to satisfy this premise.

$$dQ = EdW,$$

or

$$dQ = Epdv.$$

From the First Law

$$dQ = du + pdv.$$

From Joule's Law

$$dQ = c_v dT + pdv.$$

Then

$$c_v dT + pdv = Epdv.$$

By differentiating $pv = RT$ we obtain

$$dT = \frac{pdv + vdp}{R}.$$

Then

$$\frac{c_v}{R}(pdv + vdp) = pdv(E - 1).$$

Using $c_v/R = 1/(k-1)$ and re-arranging

$$vdp + pdv[k - E(k-1)] = 0.$$

Now let $n = k - E(k-1)$. Then

$$vdp + npdv = 0,$$

$$\frac{dp}{p} + n\frac{dv}{v} = 0,$$

which, when integrated, yields

$$pv^n = C.$$

Therefore this $p - v$ relationship characterizes the general process for which dQ/dW is a constant.

It may now be noted that for each of the other four processes described above dQ/dW is a constant. Hence each is a polytropic.

For each process the ratio E may be determined by separate calculation of work and heat by the usual methods. Then the proper exponent n may be determined from the above definition of n, i.e., $n = k - E(k-1)$. The results of such determinations are listed below:

	E	n
Constant pressure	$k/(k-1)$	0
Constant volume	∞	$-\infty$
Isothermal	1	1
Isentropic	0	k

The utility of this analysis may be extended to obtain simple expressions for dQ, dW, and du usable for any of the processes discussed above.* Using only

* Since the equations are all given in terms of dT, the work and heat expressions become indeterminate for the isothermal process.

the First Law, and the basic premise that E is a constant, the following may be obtained in terms of n or E:

$$dQ = c_v \left(\frac{k - n}{1 - n} \right) dT$$

or

$$dQ = c_v \frac{E}{E - 1} dT,$$

$$dW = c_v \left(\frac{k - 1}{1 - n} \right) dT$$

or

$$dW = c_v \frac{1}{1 - E} dT,$$

$$du = c_v dT.$$

This method undoubtedly will not contribute to a better understanding of the four basic processes, but it does present a simple and logical definition of the polytropic process. It indicates, also, that the polytropic does not include all possible processes but has a very precise restriction. It also becomes easier to understand why the polytropic process has been utilized to attempt to describe some actual compression processes in which heat was not exactly that prescribed by the isothermal nor zero as required by the isentropic, but the heat does bear a fixed relation to the quantity of work.

The Third National Surveying Teacher's Conference

Sponsored by

Committee 8, Civil Engineering Division, ASEE

and

The University of Illinois

August 3–8, 1952

Camp Rabideau, Summer Surveying Camp of the University of Illinois, will be the scene of The Third National Surveying Teacher's Conference, August 3–8, 1952. Situated in the Chippewa National Forest of Northern Minnesota and in an area famous for its lakes and Paul Bunyan lore, Camp Rabideau with an unparalleled physical plant and pleasant woodland environment offers excellent facilities for conference activities and communal living.

The Illinois Surveying Camp is located on federally-owned forest land in Beltrami County about 35 miles northeast of Bemidji. Deer and small game abound in the heavy stand of second-growth timber that covers this region. Daily rail and bus service is available from Minneapolis to the village of Blackduck which is 6 miles north of the camp. Good highways approach the area from all directions.

For further information address Brother B. Austin Barry, F. S. C., Chairman Committee 8, Civil Engineering Division, ASEE, Manhattan College, New York 71, N. Y.

Dining and sleeping accommodations will be furnished at a cost of about $25 per person for the six-day period. A reduced rate will be made for children. Reservations should be made with Dr. M. O. Schmidt, Director of Camp Rabideau, Surveying Building, University of Illinois, Urbana, Illinois.

Section Meetings

Section	*Location of Meeting*	*Dates*	*Chairman of Section*
Allegheny	Pennsylvania State College	April 18–19, 1952	E. B. Stavely, Pennsylvania State College
Illinois-Indiana	University of Illinois	May 17, 1952	D. G. Ryan, University of Illinois
Kansas-Nebraska	University of Nebraska	Nov. 16–17, 1951	Kenneth Rose, University of Kansas
Michigan	University of Detroit	May 10, 1952	W. P. Godfrey, University of Detroit
Middle Atlantic	Villanova College	May 10, 1952	S. J. Tracy, Jr., City College of New York
Missouri	University of Arkansas	April 5, 1952	R. Z. Williams, Missouri School of Mines
National Capital Area	Howard University George Washington University	February 5, 1952	W. Oncken, Jr., Bureau of Ordnance
New England	Worcester Polytechnic Institute	Oct. 18, 1952	E. T. Donovan, University of New Hampshire
North Midwest	Iowa State College	Oct. 3–4, 1952	S. J. Chamberlin, Iowa State College
*Ohio	Ohio State University		W. F. Brown, University of Toledo
Pacific Northwest	University of Washington	April 25–26, 1952	T. H. Campbell, University of Washington
Pacific Southwest	California State Polytechnic College	Dec. 29–30, 1952	S. F. Duncan, University of Southern California
Rocky Mountain	University of Wyoming	April 19, 1952	E. J. Lindahl, University of Wyoming
Southeastern	Clemson College	April 10, 11, 12, 1952	R. L. Sumwalt, University of South Carolina
Southwestern	University of Houston	April 25 & 26, 1952	H. P. Adams, Oklahoma A. & M. College
Upper New York	Alfred University	October 10–11, 1952	R. M. Campbell, Alfred University

Members of the Society are welcome at all Section Meetings

* No Date Set.

New Members

ABEGG, MARTIN G., Assistant Professor of Civil Engineering, Bradley University, Peoria, Illinois. H. Blichensderfer, R. E. Gibbs.

ANDERSON, HENRY C., Instructor in Mechanic Arts, Lincoln University, Jefferson City, Mo. C. B. Taylor, W. Jackson.

ANDERSON, WARREN R., Associate Professor of Electrical Engineering, California State Polytechnic Institute, San Luis Obispo, Calif. C. E. Knott, E. C. Glover.

AYRES, G. H., Professor of Chemistry, University of Texas, Austin, Texas. A. B. Bronwell, S. C. Hollister.

BAKER, BURTON C., Supervisor—Technical Placement, Minnesota Mining & Manufacturing Company, St. Paul 6, Minn. E. W. Johnson, W. W. Burton.

BALISE, PETER L., Instructor in Mechanical Engineering, University of Washington, Seattle, Wash. J. B. Morrison, R. W. Crain.

BENDER, LUKE R., Assistant Professor of Mechanical Engineering, Bucknell University, Lewisburg, Pa. W. D. Garman, D. W. Griffith.

BENTLEY, WILSON J., Associate Professor of Engr. and Mgmt., Oklahoma A. & M. College, Stillwater, Okla. H. G. Thuesen, M. R. Lohmann.

BROWN, CHARLES L., Associate Professor of Mechanical Engineering, Purdue University, Lafayette, Ind. O. W. Witzell, D. S. Clark.

BUCKNER, WILLIAM N., Principal, Armstrong High School, Washington, D. C. L. K. Downing, J. C. Webster.

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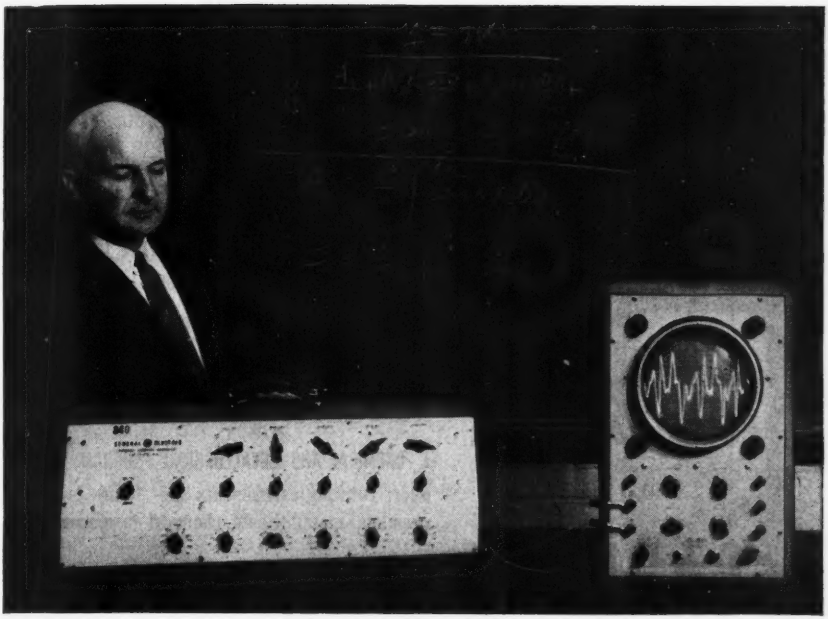

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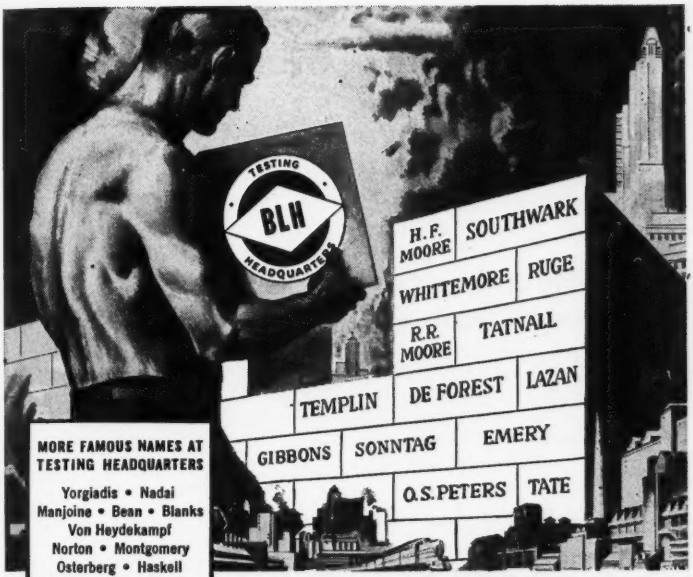

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